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DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-77-30

AQUATIC DISPOSAL FIELD INVESTIGATIONS COLUMBIA RIVER DISPOSAL SITE, OREGON

APPENDIX E: DEMERSAL FISH AND DECAPOD SHELLFISH STUDIES

by

Joseph T. Durkin, Sandy J. Lipovsky

National Marine Fisheries Service,

Hammond, ~~Oregon~~ 97121

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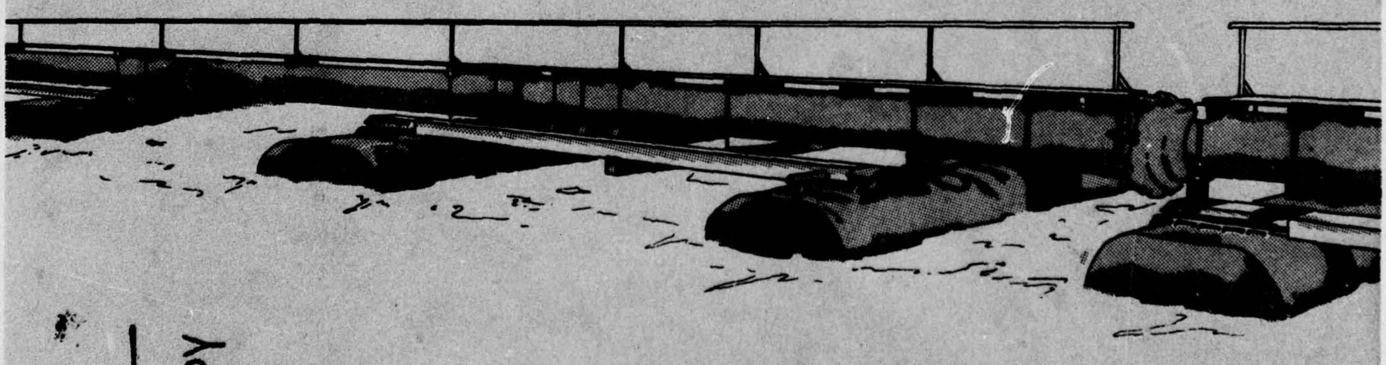

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under DMRP Work Unit No. 1A07E

Monitored by Environmental Effects Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

AQUATIC DISPOSAL FIELD INVESTIGATIONS
COLUMBIA RIVER DISPOSAL SITE, OREGON

APPENDIX A: Investigation of the Hydraulic Regime and Physical Nature of Bottom Sedimentation

APPENDIX B: Water Column, Primary Productivity, and Sediment Studies

APPENDIX C: The Effects of Dredged Material Disposal on Benthic Assemblages

APPENDIX D: Zooplankton and Icthyoplankton Studies

APPENDIX E: Demersal Fish and Decapod Shellfish Studies

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION. CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG. MISSISSIPPI 39180

IN REPLY REFER TO: WESYV 28 November 1977

SUBJECT: Transmittal of Technical Report D-77-30, Appendix E

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of one of several research efforts (work units) undertaken as part of Task 1A, Aquatic Disposal Field Investigations, of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 1A is a part of the Environmental Impacts and Criteria Development Project (EICDP), which has as a general objective the determination of the magnitude and extent of effects of disposal sites on organisms and the quality of surrounding water, and the rate, diversity, and extent such sites are recolonized by benthic flora and fauna. The study reported on herein was an integral part of a series of research contracts jointly developed to achieve the EICDP general objective at the mouth of the Columbia River Disposal Site, one of five sites located in several geographical regions of the United States. Consequently, this report presents results and interpretations of but one of several closely interrelated efforts and should be used only in conjunction with and with consideration of the other related reports for this site.

2. This report, Appendix E: Demersal Fish and Decapod Shellfish Studies, is one of five appendices published relative to the Waterways Experiment Station Technical Report D-77-30 entitled "Aquatic Disposal Field Investigations, Columbia River Disposal Site, Oregon." The titles of the contractor-prepared appendices of this series are listed on the inside front cover of this report. The main report provides additional results, interpretations, and conclusions not found in the individual appendices and provides a comprehensive summary and synthesis overview of the entire project.

3. The purpose of this study, conducted as Work Unit 1A07E, was to describe the composition and spatial and temporal distribution of demersal finfish and decapod shellfish in the mouth of the Columbia River. In addition, food utilization by dominant species and the effects of dredged material disposal on these dominant species were studied. The report includes a discussion of the observed trends in community structure, abundance, and distribution, as well as the feeding habits of the 13 dominant species. Also discussed are the effects of dredged material disposal on demersal fish and decapod shellfish.

4. A conclusion of this report, based on the methods of analysis selected, was that community structure measures such as diversity and species richness were depressed for a 3- to 6-month period at the disposal site following disposal; however, no test of significance was performed to substantiate this speculative conclusion. It was also suggested that these same measures of community structure were similar to reference sites 7 months after disposal. The authors also stated that there were significant spatial differences in catch data between sites north and south of the Columbia River.

5. The results of this study may be particularly important in the selection of open-water disposal sites and the timing of disposal operations in the study area. However, personnel in the DMRP are of the opinion that several factors must be kept in mind before the results of this study may be applied to the regulation of disposal practices at the site.

a. The method of data analysis chosen to evaluate the spatial differences in length frequencies was a Kolmogorov-Smirnov two-tailed test and as such, definitive statements regarding differences in mean lengths cannot be made. The two-tailed test can, at best, only suggest that there is a difference in the two populations being considered. In addition, the rationale behind pooling the data from four sites so that they can be compared with the test site is questionable, especially when the authors state that there are significant differences in fish populations north and south of the river mouth.

b. Conclusions based on the analysis of variance of the catch data only considered the main effects of station or site differences and did not consider the interpretation of the interaction term between sites and time. It is the opinion of DMRP personnel that this interaction term is the key factor in assessing the effects of dredged material disposal.

c. Inferences from the data regarding spatial differences in the length frequencies and size structure of the demersal fish populations in the study area are confounded since the data measured at each sample site were combined and collectively interpreted.

d. The length of the individual trawls was not considered in the catch-per-unit-effort determinations. Examination of the data indicates that there was considerable variation in the length of the respective trawls and that on the average, tow lengths at the test site were significantly less than at other sites, despite the fact that the duration of each trawl was 5 minutes. This variation undoubtedly accounted for part of the variation in the catch data; however it is not addressed in the report.

WESYV 28 November 1977

SUBJECT: Transmittal of Technical Report D-77-30, Appendix E

6. In light of the items mentioned herein, the reader is cautioned as to the validity of the data interpretations and conclusions presented in this report. Inferences with respect to the impacts of disposal on the fish and shellfish communities must be considered tenuous and highly speculative and must only be made in conjunction with the items outlined above.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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→ Information is provided on 51 finfish and 13 decapod shellfish found at five sites off the Columbia River mouth. The effects of a controlled sediment release by hopper dredges on these indigenous species were studied between October 1974 and April 1976. An initial nine-month phase provided biological information at four sites with a fifth site included in July 1975, as an experimental deposition area. The dredges HARDING and →
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20. ABSTRACT (Continued).

BIDDLE released 548,519 m^3 of sediment between July 9 and August 26, 1975. Sampling continued during and after sediment release until April 1976.

Trawling effort consisted of 151 tows 5 minutes in duration and yielded 86,931 finfish and 97,360 decapod shellfish. Numerically important were anchovy, smelt, sole, poachers, snailfish, shrimp, crab, tomcod, and sanddab. Nonparametric test indices of community diversity usually decreased at the experimental test site during and after sediment deposition. However, diversity indices subsequently recovered and were comparable to those of the other sites by April 1976. Characteristics of dominant species are described including size range, food preference, and seasonal availability. Using data on dominant species, statistical tests indicated catch differences usually occurred between sites and between months; further, individuals at the test site were smaller. Tests were limited by small numbers of species and individuals taken at the test site during and after sediment deposition.

Finfish food studies revealed preferential feeding habits. Five organisms were extensively consumed and included a cumacean, amphipod, mysid, shrimp, and anchovy. Changes in finfish food utilization were difficult to assess, but consumption of small organisms diminished and utilization of shrimp and anchovy increased.

Data indicate that substantially more finfish and decapod shellfish reside at north and central sites during normal channel maintenance periods. The experimental release of sediments was detectable by diversity indices.

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PREFACE

The work described in this report was performed under Intra-Army Agreement No. WESRF 76-26 between the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the National Marine Fisheries Service (NMFS), Hammond, Oregon. The research was sponsored by the Office, Chief of Engineers (DAEN-CWO-M), under the Civil Works Dredged Material Research Program (DMRP). The study, which was part of the Aquatic Disposal Field Investigation, Columbia River Disposal Site, Oregon, was conducted during the period October 1974 through April 1976.

We would like to express our appreciation to Mr. George Snyder, Assistant Director, Field Research Programs, NMFS, Seattle, and to the following members of the NMFS Hammond Station staff: Nick Zorich for his seamanship and fish trawling experience; Roy Pettit for his mechanical ability and engineering skill; and Mary Lee Brown for graphics, report preparation, and compilation of data. We would also like to express our appreciation to Mr. James Shelton, Liaison Coordinator, Columbia River Program Office, and David Misitano, NMFS, Mukilteo, for the initial food utilization studies in January and March 1975. We are indebted to Donald Worlund, NMFS, for statistical assistance and Michael Richardson, OSU, who provided background information regarding numerical classification methods. We also

wish to thank those individuals who assisted in identification and confirmation of several benthic invertebrate, decapod shellfish, and finfish species: William Colgate, Beverly Buchanan, Michael Kravitz, Howard Jones, Charles McConnell, and Wayne LaRoche of OSU, and Herb Sanborn of NMFS, Seattle. Thanks are also due Joanne Bjork and Anne Naab for their able assistance at the Hammond Facility.

The report was prepared for the Environmental Impacts and Criteria Development Project (Dr. Robert M. Engler, Manager) as part of Task 1A: Aquatic Disposal Field Investigations. The contract was managed by Mr. Charles G. Boone, Environmental Resources Division, under the general supervision of Dr. John Harrison, Chief, Environmental Effects Laboratory.

COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of the WES during the conduct of this study and Mr. F. R. Brown was Technical Director.

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AQUATIC DISPOSAL FIELD INVESTIGATIONS

COLUMBIA RIVER DISPOSAL SITE, OREGON

APPENDIX E: DEMERSAL FISH AND DECAPOD SHELLFISH STUDIES

PART I: INTRODUCTION

Background

1. Specification of disposal sites for sediments dredged from approved channel maintenance or deepening projects is a responsibility of the U.S. Army Corps of Engineers. The possible adverse impact of dredged material disposal upon indigenous aquatic life is a concern of the National Marine Fisheries Service (NMFS) and other governmental agencies assigned to protect and conserve biological aquatic resources. Sediment disposal can smother fish; cover vertebrate and invertebrate eggs and larvae; release accumulated gases, pesticides, or metallic pollutants; increase the biological oxygen demand load; eliminate benthic food organisms; and create turbidity.

2. Little is known about effects upon fish of sediment disposal at approved disposal sites off the Columbia River mouth and if such effects can be measured. A short-term study conducted by NMFS for the Portland District Corps of Engineers suggested a numerical reduction of fish at ocean disposal sites following hopper dredge use (Durkin 1975). However, the short-term sampling effort and

limited available background information made it difficult to determine if seasonal or chance variation may have affected the catches.

Purpose and Scope

3. In November 1974, the Waterways Experiment Station (WES) of the U.S. Army Corps of Engineers (CE) selected the mouth of the Columbia River (MCR) as one of four geographic areas to be studied as part of an ongoing Dredged Material Research Program (DMRP). Fishery investigations were conducted by NMFS while Oregon State University and University of Washington research teams studied other biological, physical, and chemical aspects of the impact of disposal of dredged material at MCR.

4. The purpose of NMFS portion of the current MCR study was to describe the composition, spatial, and temporal distribution of demersal finfish and decapod shellfish. Food utilized by dominant species was studied as well as the impact of dredged material disposal on finfish and decapod shellfish at the experimental test site. In order to correlate information gathered during NMFS surveys with that of the other investigators, specific biological and physical data were transmitted to WES on General Data Form 2065. Once computed, the data should provide information necessary for determining overall effects of ocean disposal at the MCR site.

5. The initial study phase (October 1974-June 1975) involved sampling at four preselected sites (Durkin and Lipovsky 1975). Two of the sites were CE dredged material disposal sites B and F and the other two sites served as comparative sampling areas. A fifth site, added in July 1975, had no prior history of use and was selected for experimental testing of sediment disposal. Baseline studies continued at the four initial sites from July 1975 through April 1976, while sampling at the designated test site continued after the hopper dredge ceased its experimental dumping activities.

Site Description

6. The disposal sites normally used by the CE hopper dredges, the north and south comparison sites, and the experimental test site used after July 1975 are shown in Figure E1. To simplify discussion in this report the sampling sites are designated A,B,C,D, and E with A being the northernmost site. Corps designation, NMFS name, and geographic location are listed below.

	Site A	Site B	Site C	Site D	Site E
Latitude	46°15'N	46°14'N	46°12'N	46°11'N	46°11'N
Longitude	124°9'W	124°9'W	124°8'W	124°8'W	124°6'W
NMFS Name	AA-25	AA-26	AA-37	AA-44	AA-42
CE Designation	-------	B	F	-------	Exp.(G)
Buoy Marker	-------	1	2	-------	D

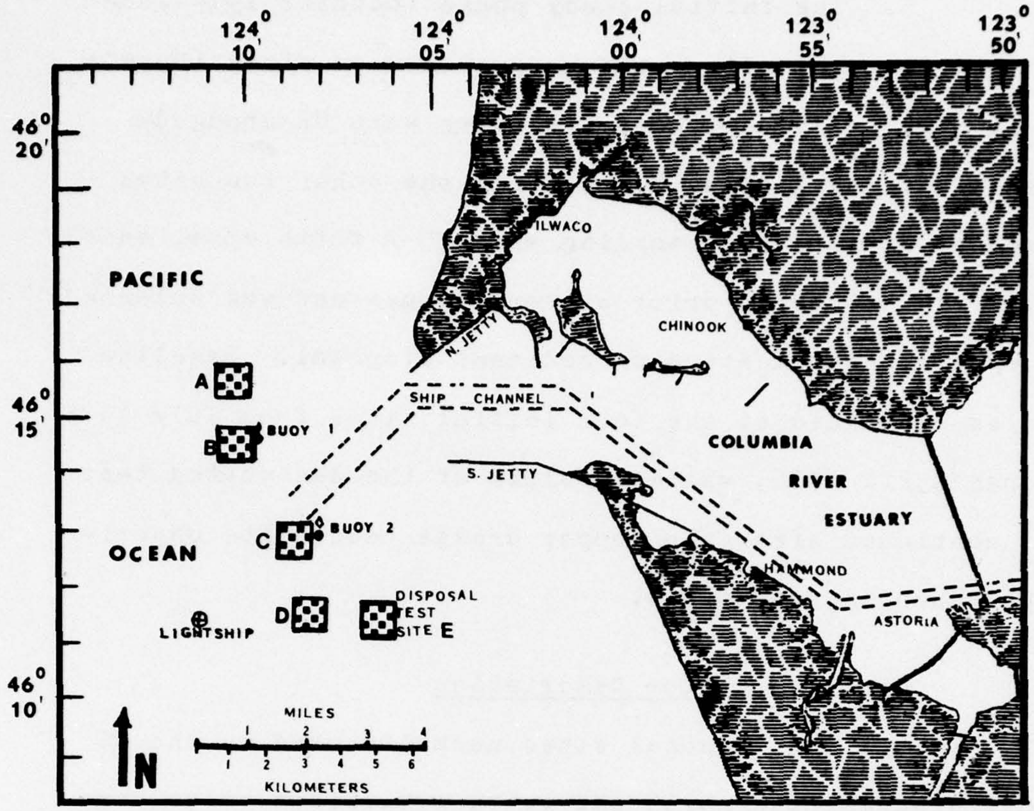

Figure E1. NMFS fish and decapod shellfish trawl sites off the Columbia River mouth.

7. Hopper dredge activity at the mouth of the Columbia River and its estuary usually is limited to a March-through-October period. In order to complete the initial study phase without additional sediment deposition, CE personnel placed the dredged material at a site near the end of the North Jetty or at an approved site within the estuary. The experimental disposal site (E) was used by the hopper dredges HARDING and BIDDLE from 9 July to 26 August 1975. Sternberg et al. (1976) reported that a total of 548,519 m^3 was deposited in "a recognizable bathymetric feature with a circular shape 2500 ft. (758 m) in radius and 5 ft. (1.5 m) in elevation. The volume of sediment comprising the feature is 424,000 yds^3 or 71 percent of the total dumped."

8. Depths at the sample sites ranged from 17.5 to 40 m. Salinities and temperatures (Appendix EI) recorded on the bottom before and after each tow were averaged and plotted for each month at each sample site. Temperatures ranged from 6.5 to 10.9° C, while salinities ranged from 28.8 to 32.5 ppt. The near-bottom water at all sites was usually warmest in November and coldest in June and July. Salinities were lowest during June and July and highest during August. Additional information regarding net size, location, directional heading, distance, and catch of each tow is listed in Appendix EII.

Literature Review

9. Biological information on the specific sites is limited, but a book titled <u>The Columbia River Estuary and Adjacent Ocean Waters</u> by Pruter and Alverson (1972) provides the greatest single source of biological information about the study area. Pruter (1966, 1972) described the commercial fisheries of the Columbia River and its contiguous ocean waters. Methods of harvesting specific fish and the landing tonnages of many species through the known histories of the fisheries were presented.

10. Pearcy (1972) described a group of aquatic fauna caught 28 to 285 km off the Oregon coast using midwater trawl nets and plankton nets between 1961 to 1968. Conventional commercial nets have larger mesh and allow the escape of juvenile forms and many of the smaller species. McCauley (1972) reported on decapod crustaceans and other invertebrates captured in 246 otter-trawl tows and 10 dredge samples in 0 to 50 m depth off the Oregon coast and other samples ranging from 50 to 3000 m. Pereyra and Alton (1972) surveyed decapod crustaceans and other epibenthic invertebrates directly off the Columbia River mouth; however, the depths of their samples ranged from 91 to 2103 m. Alton (1972) described the commercial otter-trawl catches of demersal fish species found off the northern Oregon coast in depths ranging from 91 to 2121 m. The surveys occurred between 1961 and 1966 and produced

92 identifiable species of fish.

11. Further geographic references to finfish or decapod shellfish species distribution occurring in the vicinity of the Columbia River mouth that were used in this study included Barss (1976); Clemens and Wilby (1967); Demory (1975); Demory and Bailey (1967); Frey (1971); Haertel and Osterberg (1966); Hart (1973); Hosie (1976); Kozloff (1974); McAllister (1963); Miller, Gotshall, and Nitsos (1965); Miller and Lea (1972); Roedel (1953); Robinson (1976); Schultz (1969, 1936); Smith and Carlton (1975); TenEyck and Demory (1975).

12. Little of this information regarding commercial and noncommercial adult and juvenile species of fish is site specific to the approved MCR Corps of Engineers dredged material disposal areas. Temporal and spatial changes of indigenous species had not been documented in this particular area, known for its characteristic strong currents, summer upwelling, and seasonal high volume influx of fresh water.

PART II: METHODS AND MATERIALS

Sampling Program

13. The sampling program of the demersal zone was conducted monthly as weather conditions and commercial crabbing permitted. It was found to be possible to trawl during 15 of the months, but trawling was impossible in December 1974, February and October 1975, and March 1976. Concentration of commercial fishing gear for Dungeness crab (Cancer magister) from December to March prevented trawling at sites A, B, and E.

14. The northern site, A, provided a basis for comparison with catches at disposal site B while the southern site, D, provided a basis for assessing catches at disposal site C. Site D also provided a basis for comparison of catches at experimental test disposal site E. Collection strategy was to make parallel trawl tows at a minimum of two sites a day (usually completing monthly sampling in two or three days). Parallel trawl tows of 5 min duration normally were made at each site. On one occasion it was possible to complete the monthly samples in a single day.

15. Samples at the experimental test site E were sampled more frequently in July and August 1975 to determine if numbers of finfish and decapod shellfish changed from the immediate effects of sustained sediment disposal. Test site E was not established nor a marker

buoy positioned until two weeks before actual sediment disposal commenced, thus minimizing predisposal sampling. Furthermore, a suggested pattern for sediment disposal at the test area that would have resulted in more accurate sampling was not followed by the dredge. The plan called for the hopper dredge to release sediments along a linear route on either side of two buoys approximately 1 km apart resulting in an oval deposition pattern. Instead, sediment sometimes was released at distances of up to 400 m from the buoy as the hopper dredge made a 180° turn (see photograph in the DMRP Information Exchange Bulletin, U.S. Army CE, 1976). The dredge's maneuver was impossible to follow with trawl gear and an unknown segment of each trawl tow taken at test site E was very likely made outside the actual sediment deposition zone.

16. Fish and decapod shellfish were sampled with semiballoon shrimp nets having an 8-m (actually 7.6 m) headrope and a 9.8-m footrope. The net was composed of 38-mm stretched mesh overall and a 12-mm knotless cod-end liner. Trawl doors were 91 cm long and 46 cm high and each weighed 13.2 kg. A smaller semiballoon shrimp net having similar mesh size with a 5-m (4.9 m) headrope and a 6-m footrope and 55 cm by 33 cm trawl doors weighing 7.9 kg each was used in the initial phase of the study. The design of similar nets was reported by Bullis (1951) and its application described by Mearns (1974); Swingle, Bland,

and Tatum (1976); and Wilk and Silverman (1976).

17. Mearns and Stubbs (1974) determined that catch differences existed between nets of similar size manufactured by different companies. Catches can also be influenced by towing speed, otter door size, and bridle length. We observed during this study that differences in catch occurred between an 8 m and a 5 m net manufactured by the same company. Both number of species and total numbers of individuals captured were related to the net size. The larger net captured more species and individuals per tow (Appendix EIII). A decision was made to use the 8 m trawl net exclusively for the remainder of the MCR study based on test results. A larger net, larger mesh size, longer tows, and a higher trawling speed may have produced additional species and larger individual specimens. These possible approaches were rejected because sampling would be over unimpacted sites and slow-moving juvenile fish and shellfish would pass through large mesh.

18. Sampling was conducted with a 12.2 m vessel formerly used as a utility boat by the U.S. Coast Guard. A hydraulically powered winch and cable reel was mounted on a modified crab pot boom and positioned on the vessel's port aft gunwale. Net doors were attached by a 15.2 m bridle to a single 4.75 mm stainless steel cable leading to the winch. The procedure upon arrival at each site was to determine depth by sonar and position by radar and visual

reference to marker buoys. A Beckman RS5-3 salinometer with a 46 m probe was used to determine temperature, salinity, and conductivity of the bottom and surface waters before and after each tow. Each sample trawl tow began following release of 200 m of cable while the vessel was under way. Tows were 5 min long at constant engine speed at a fixed compass heading parallel to the preceding or following tow. Tow distance was influenced by tidal currents, wind, and waves. Linear distance of trawl tows was determined for 147 of the 151 sampling efforts. Distance was not determined for the first 4 tows (see Appendix EII). The mean tow distance was 366.75 m with a Standard Deviation of 154.10 m and Standard Error of 12.71 m. Average trawling speed based on the mean distance was 7.34 km/hr.

Identification of Catch

19. The net was retrieved upon completion of each 5-min tow, and the net's contents placed in numbered containers. At the conclusion of sampling, the individual containers were taken to the Hammond NMFS Biological Facility. All specimens were counted and weighed individually or collectively. At least 50 individuals of each species were randomly selected from each tow, measured to the nearest millimetre from tip of snout to caudal fork, and weighed to the nearest gram. Fish were identified based on the following references: Clemens and Wilby (1967); Hart (1973);

Hitz (1965); McAllister (1963); Miller, Gotshall, and Nitsos (1965); Miller and Lea (1972); Roedel (1953); and Schultz (1936). Common and scientific names are those designated by the American Fisheries Society (Bailey et al. 1970).

20. From January 1975 through January 1976, stomach cavities of a subsample (up to 27) of the numerically dominant fish from each tow were injected with a 10 percent formalin solution buffered with Borax. This procedure took place immediately after the catch was brought aboard the vessel. The injected fish were placed in plastic bags, identified with the appropriate tow number, and covered with a weak formalin-seawater bath. After being weighed and measured in the laboratory, the whole fish were returned to the bags containing the formalin-seawater preservative and held for later examination.

21. Beginning in February 1976, a similar procedure was followed except that fish were placed in plastic bags according to tow but were not covered with the formalin-seawater bath. Immediately after being weighed and measured in the laboratory, stomachs were removed at the throat and junction of the pyloric caecae and placed in small glass vials containing the buffered formalin solution. The vials were labeled with a number identifying the fish from which the stomach was taken and stored until analysis.

22. At the laboratory stomachs were emptied into a watch glass and moistened with water. Using a dissecting microscope, individual organisms were identified to the lowest possible taxonomic category. Total weights to 0.01 g were taken and the numbers of each organism recorded for each fish. Before weighing, each group of like organisms was dried on filter paper for 5 to 10 min. A small reference collection was prepared and maintained.

23. In some instances, digestion of prey items had advanced to the stage that the stomach contents were unidentifiable. Larger organisms and those with bones, carapaces, or shells were digested at a slower rate than those composed mainly of soft tissues, setae, or numerous body appendages.

24. Identifications of food organisms were based upon the following authorities: Banse and Hobson (1974); Barnard (1962a, 1962b, 1969, 1972); Barnard and Given (1960); Brodskii (1950); Fulton (1968, 1972); Given (1964); Hart (1930); Hartman (1947); Keen and Coan (1974); Kozloff (1974); Schultz (1969); Smith and Carlton (1975); Tattersall (1951); Threlkeld (1973); and Yamaji (1974a, 1974b).

25. Decapod shellfish captured in the trawl tows were counted individually and weighed either singly or collectively. A randomly selected group of each species (up to 50) was measured to the nearest millimetre and

weighed to the nearest gram. Shrimp were measured from the tip of the rostrum to the tip of telson for total length. Crab widths were measured across the carapace to the notches in front of the tenth anterolateral teeth. Pagurids (hermit crabs) were simply counted. Identification of decapods was based on some of the references listed earlier such as Kozloff (1974) and Smith and Carlton (1975). Other sources were Isreal (1936), Schmitt (1921), and Word and Charwat (1976).

26. Crangonid shrimp are numerous within and off the Columbia River mouth. During the initial study phase (Oct. 1974-June 1975), it was incorrectly assumed that all *Crangon* sp. captured were oceanic extensions of two bay species, *C. nigricauda* and *C. franciscorum*. The same two species were reported by Haertel and Osterberg (1966) in the Columbia River estuary, Krygier and Horton (1975) in Yaquina Bay, and Isreal (1936) in San Francisco Bay. Separation and identification of *C. franciscorum* is not difficult; however, Oregon State University specialists studying benthic invertebrates at the disposal sites determined the presence of several other *Crangon* species with characteristic wide chela, in addition to *Crangon nigricauda*, such as *C. alaskensis elongata*, *C. communis*, *C. alba*, and *C. stylirostris*. Reexamination of specimens previously classed as *C. nigricauda* revealed that misidentification had occurred, and it was felt the *C. stylirostris* and *C. alaskensis* have

been numerically more abundant than C. nigricauda. Other than Crangon franciscorum, separation of the crangonids was not attempted for the final phase of the report, and these have been grouped and listed as Crangonid species.

Analysis

27. Several testing methods were used to describe the finfish populations found at the sampling sites. An analysis of variance (ANOVA) between the sites was confined to those four months in which duplicate tows were made at the test site and other four sampling sites, (July, August, and September 1975 and April 1976). These months alone provided the ANOVA comparison. Each of the 13 numerically important finfish and decapod shellfish species was examined to determine if there were significant differences ($p=0.05$) in catches between sites, between months, and the interaction among sites and months. Paired monthly trawl tows (replicates) at each site were established to form subclasses. Catch data ($n+1$) were converted to natural logarithms to meet the assumptions inherent in use of ANOVA.

28. With each species 2-way (see Appendix EIV) ANOVA tests, a quantity z was calculated to test for differences (at the 5-percent level) between pairs of means at each site. The procedure used (Tukeys test) follows that presented by Snedecor (1956). Factor z was calculated by:

$z = Q\sqrt{\frac{e}{E}}$ where e is the error mean square; Q is a value in the Studentized Range depending on the degrees of freedom associated with e and the number of sites; and E is the number of observations at each site.

29. Nonparametric Shannon-Weaver diversity described by Clifford and Stephenson (1975) was used to define community structure. Diversity is useful for comparing temporal community change and stress induced by external factors (Mearns, 1974 and Weber, 1973). Dahlberg and Odum (1970) note that "Species numbers diversity is generally a more sensitive and reliable index of environmental health than are individual 'indicator' organisms." The Shannon-Weaver information theory (Shannon and Weaver, 1963) ranges from low to high diversity indices as both the number of species and equitability of species abundance increase. The formula used to compute the Shannon and Weaver index (H') was $H' = -\Sigma pi \log_2 pi$ where $pi = \frac{Xa}{\Sigma N}$; Xa is the number of individuals of a given species in a sample; and N is the total of all individuals in the sample.

30. Species richness (SR) or Margalef index of diversity (Margalef, 1951) measures species diversity. The formula used was $SR = \frac{(S-1)}{\ln N}$ where S is the number of species and ln N is the natural logarithm of the total catch.

31. The evenness index (J') of fish catches by Pielou (1966) was used to describe equitability of species in a sample. The formula was $J' = \frac{H'}{\log_2 S}$ where H' is the Shannon-Weaver index and S is the number of species in the sample.

32. Other measures of the community structure used to describe the finfish population were catch per unit of effort (CPUE), which was measured as catch per minute of trawl effort. The average number of individuals per species at each site for each month was measured and compared with those appearing at the other sites.

33. Lengths of numerically dominant species were tabulated and length frequency histograms prepared which indicated size groups. Kolmogorov-Smirnov two-sample tests (Siegel, 1956) of the comparative lengths were undertaken to describe a spatial difference in lengths of a finfish species occurring at the test site and the four preselected sites. Determination of the critical value d corresponding to a 5 percent level of significance was achieved by the formula $d=1.36\sqrt{\frac{a+b}{ab}}$ where a is the total individuals measured at the test site and b is the total individuals measured at the four remaining sites. If a 10 percent significance level is used, the factor 1.22 is substituted for the factor 1.36. Should comparative cumulative percent of a species length differ by more than

the critical value d, length frequencies are significantly different.

34. Behavioral characteristics of finfish tending to diminish the effectiveness of some of the tests included:

<u>a</u>. Presence or absence of a schooling species.

<u>b</u>. Vertical migrations of some species in the water column, particularly those classified as pelagic but captured in the demersal zone.

<u>c</u>. Seasonal inshore migrations (immigrations) and offshore migrations (emigrations) of some demersal species.

<u>d</u>. Obvious and continuing spatial differences in numerical proportions of finfish species found to the north and south of the Columbia River entrance channel.

<u>e</u>. The probable selectivity of the trawl net for some species and some size groups of fish.

PART III: RESULTS

Community Structure

Index of diversity

35. The Shannon-Weaver (H') index and other indices for diversity were calculated whenever possible for each site and month from October 1974 through April 1976. Data from parallel tows at each site were combined for computation of diversity indices. Where sampling occurred more frequently than once a month at a site, the data selected corresponded nearest with sampling dates at other sites.

36. As shown in Figure E2, diversity (H') at various sites was variable between November 1974 and May 1975. The instability was definitely related to presence or absence of schooling northern anchovy juveniles at a particular site. When anchovy were captured a low diversity resulted because they numerically dominated the catch. Usually the index exceeded 2.0 at all sites when anchovy were not numerous. Seasonal changes in the Shannon-Weaver diversity index may occur in the MCR area, but such a determination would require further study and also would require excluding the masking effect of northern anchovy. Since anchovy comprised 47 percent of the total catch, this does not seem reasonable.

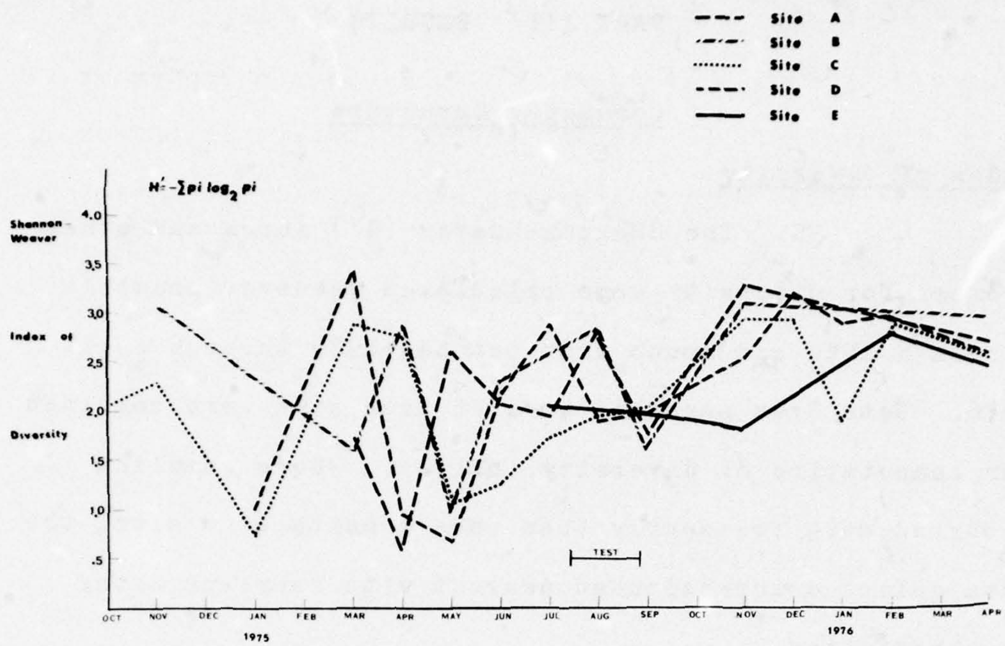

Figure E2. The indicated diversity (Shannon-Weaver function) of demersal-associated finfish from October 1974 to April 1976. Sampling at test site E began in July 1975.

37. Diversity at experimental test site E ranged from 2.0775 in July 1975 to 2.0348 in September 1975. These indices did not differ substantially from the other sites during the dredged material deposition period. However, indices at test site E were lowest in subsequent months of November 1975 and February and April 1976. This suggests a latent lower diversity which may be related to sediment deposition.

Index of species richness

38. The species richness is expressed by a simple ratio between total species and total number of fish. The index determined at each sampling site for each period is presented in Figure E3. A definite lower trend based on fewer fish and species resulted at experimental test site E following the July 1975 sampling period. Species richness indices at the experimental test site did recover in February 1976 and were similar to the other four sites in April 1976. The species richness indices for all sites are comparable to those reported by Dahlberg and Odum (1970).

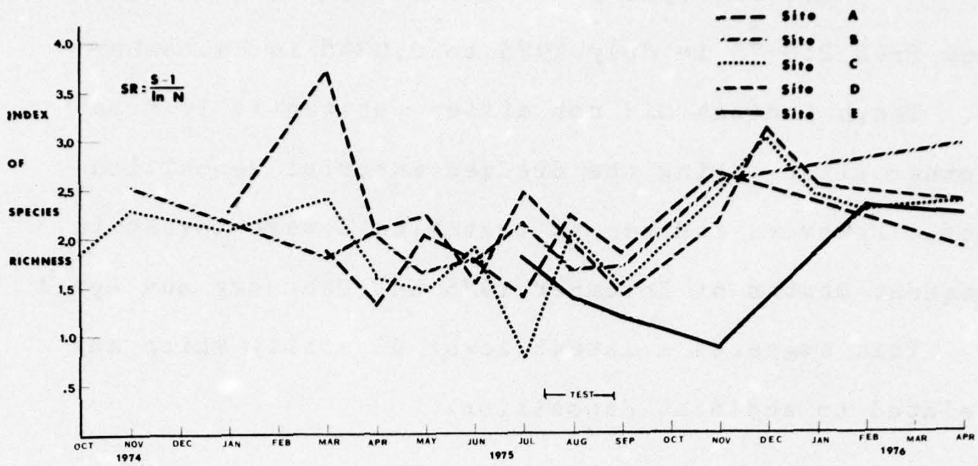

Figure E3. Species richness index of diversity for trawl-caught finfish between October 1974 and April 1976. Test site E values began in July 1975.

Index of evenness

39. The evenness or equitability index for the five sites is presented in Figure E4. As with prior indices, instability occurred from November 1974 to June 1975 because of presence or absence of northern anchovy schools. Indices at all sites were relatively stable thereafter. A seasonal trend as reported by Dahlberg and Odum (1970) was not apparent. Differences in evenness at the experimental site and other sites were minimal in July and August 1975. From September through November 1975, the experimental test site had the highest evenness rating reflecting the consistent numerical presence of those species apparently tolerant of sediment disposal.

Average catch and number of species

40. The average catch of fish per minute of trawling effort (Figure E5) and average monthly number of finfish species caught per tow (Figure E6) are additional methods to determine interrelationships between sites. They also show seasonal variation and in particular the effects of sediment disposal at experimental site E. Northern anchovy presence greatly affected the initial study phase CPUE delineation. After July 1975, CPUE at the test site was consistently low during the disposal and postdisposal

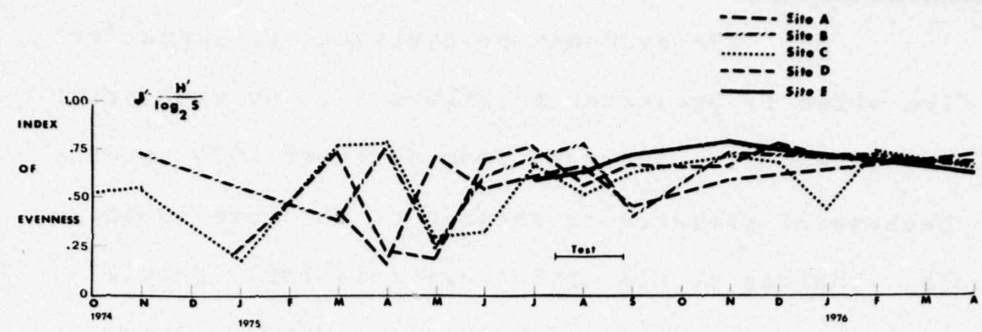

Figure E4. Indices of evenness diversity for demersal finfish captured between October 1974 and April 1976. Test site E values begin in July 1975.

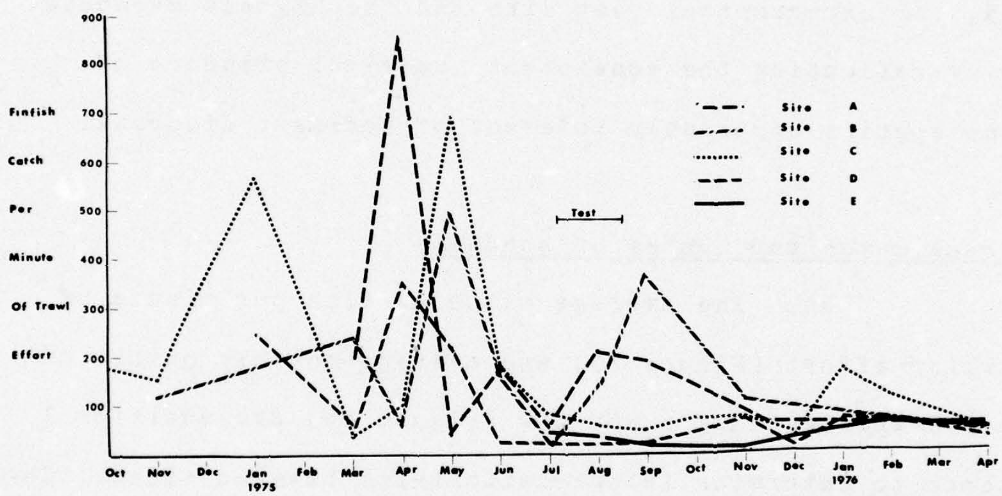

Figure E5. Comparative numerical catch of finfish per minute of trawl-sampling effort between October 1974 and April 1976.

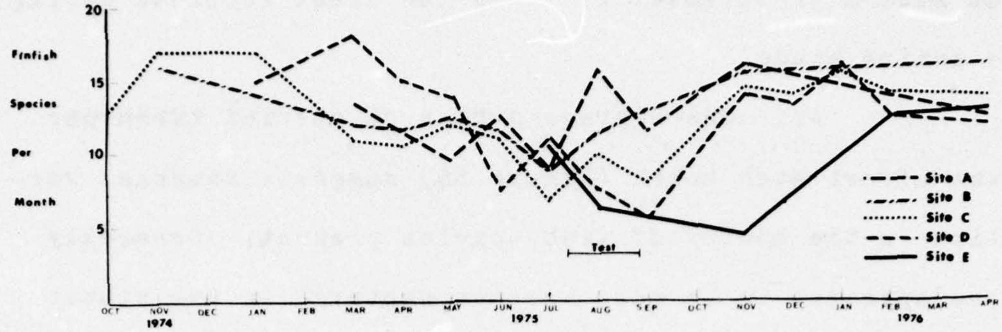

Figure E6. The average monthly number of finfish species captured between October 1974 and April 1976.

periods. An indicated 11.5 fish per minute sampling at test site E in November 1975 was the least recorded during the entire study.

41. The average number of species taken per trawl effort each month (Figure E6) suggests seasonal variation in the number of fish species present. Generally there appeared to be more species captured in the winter and spring than during summer and autumn. Species number at site D and test site E was low in July 1975 and even lower in September 1975. Average trawl catches at experimental test site E had the lowest number of species of all sites in August, September, and November 1975; thereafter they increased and were similar to all sites in April 1976.

Finfish Catches

42. The 151 trawl tows made during the study captured 86,931 finfish (Table E1). Fish included 51 species representing 21 families and 3 groups of larval fish belonging to the osmerid, scorpaenid, and pleuronectid families. The table provides the numerical proportion that each species contributed to the total catch. The list also provides a measure of the frequency of occurrence for each species for the trawl tows. For example, butter sole,

which made up 8 percent of the total catch, were taken in 96 percent of the sample tows. Also, northern anchovy, which comprise over 47 percent of all finfish, occurred in only 66 percent of the tows. Of the 51 species, 11 species represented nearly 95 percent of the total catch. These were considered numerically dominant forms and selected for more specific analysis.

43. A description of each of the 11 finfish species is presented in the following order: the quantity captured, frequency of occurrence, and seasonality is described. A length-frequency histogram, based on randomly selected individuals from each sample, provides information on size structure of the population. The lengths of species captured at the experimental site were compared with those captured at other sites during selected months when adequate numbers were caught and there was equal sampling effort at the sites. The months of July, August, and September 1975 and April 1976 were used for an ANOVA for numerical, spatial, and temporal differences in each population.

44. A composite of the significance relationship for each of the 11 finfish species is presented in Table E2. Food items consumed by the finfish are described

as well as graphs showing the numerical and weight values of each prey group. Food habits of those fish captured at the test site are compared to those taken at other sites when possible. Food consumption specific to the experimental site is also discussed.

45. Appendix EV was prepared as a general introduction to the food organisms. Each category of food item is described briefly, followed by documentations of predation on the item and literature citations. Table E3 presents the food items encountered in terms of total numbers and total weights during the entire study period. Table E4 is a monthly food item list for the experimental dump site.

46. While the species composition changed little immediately postdisposal, the numbers of cumaceans, copepods, mysids, and amphipods were decreased while decapods and teleosts increased in number. The few items recorded during the winter months reflects the reduced sampling effort at the dump site because of inclement weather and obstructive crab pots.

Northern anchovy (Engraulis mordax)

47. Northern anchovy are slender, silver fish ranging in length to 24.8 cm but usually are less than 18 cm. They rarely exceed 4 years of age. Their range is from Cape San Lucas, Baja California, to the Queen Charlotte

Islands of Canada. Anchovies are utilized for the production of oil and meal and are also used as bait. Their greatest value is as food for other species of fish.

48. The anchovy catch accounted for 40,909 individuals and numerically dominated the finfish captured at the five sites. Though considered pelagic, the schooling species was taken frequently and in large numbers with our demersal shrimp trawl. The majority of anchovy were juveniles and encountered during the initial phase of the study. The erratic community structure indices reflect their presence or absence during this period.

49. Anchovy were principally fish of the smaller size groups. The overall length range of anchovy was 42 to 148 mm. Young-of-the-year entered the catch in November 1974 joining older age groups but replaced the older fish and dominated the catch in January 1975 (Figure E7). The catch data suggest this species may inhabit different levels of the water column depending on age, season, and perhaps food preference. Since few anchovy were captured at test site E during and after July 1975, there was no basis to compare their lengths with anchovy at other sites.

50. An ANOVA for northern anchovy is based on their numerical relationships at the five sites (Table E2). The months of July, August, September 1975 and April 1976 are the base time periods when comparative sampling was conducted at all five sites. Significant differences existed

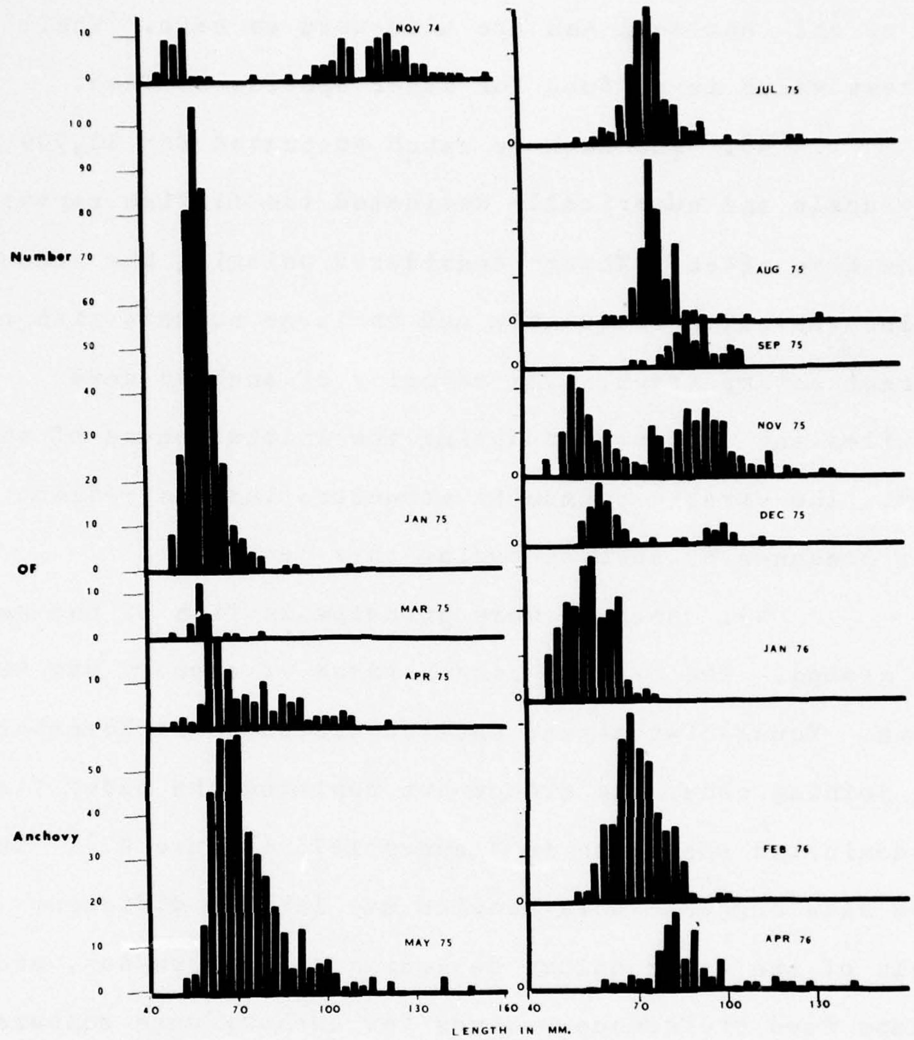

Figure E7. Monthly length-frequency histogram of northern anchovy (<u>Engraulis mordax</u>) captured with trawl gear.

between catches at the five sites. Catches did not differ significantly between months. The differences between sites appear to be consistent from month to month. In general it was noted that anchovy were frequently taken at northern sites A and B and only sporadically at sites C, D, and E.

51. The Studentized Q-test provided a means to align the sites in order to show which differ or do not differ significantly from each other.

LARGEST MEAN ________________ SMALLEST MEAN

Site	Site	Site	Site	Site
A	B	D	C	E
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
2.7350	2.3225	0.7287	0.3737	0.1375

Those means above the same line do not differ significantly (5 percent level of significance) from one another.

52. The Q-test of the difference in mean catch between pairs of sites at the 5 percent probability was based on a computed $z=2.2329$. The test indicates there was no significant difference in anchovy CPUE between northern sites A and B and southern site D. There also was no significant difference between sites E, D, C, and B. There was a significant difference in the anchovy catch between sites A and C and E, indicating a spatial difference

in anchovy CPUE (index of abundance) at the sites during and after the experimental disposal period.

53. Examination of stomach contents of anchovies captured off the mouth of the Columbia River indicated a primary diet of phytoplankton (Figure E8). Phytoplankton is listed as "other" on the chart. The diet composition was similar numerically and gravimetrically for all months. The copepods <u>Calanus</u> sp. were consumed in January 1975 and <u>Pseudocalanus minutus</u> in May 1975. A few cumaceans, <u>Diastylopsis dawsoni</u>, were eaten during April 1975. Generally, however, the diet was consistent over the sampling months.

54. Different techniques were required for analyzing stomach contents of anchovies than for fish species consuming macroplankton or macroinvertebrates. A specialized problem of anchovy food analysis is rapid digestion of phytoplankton, resulting in a predigested brown mass and an absence of individual cells. The numerically dominant anchovy, more than any other fish species, utilized the primary trophic level as food.

55. Northern anchovy stomach contents were examined from the experimental site in only April 1976. Numerically and gravimetrically, unidentified animal material was the only food item encountered. Since one fish with food in the gut was sampled, no inferences can be made regarding the effects of disposal. One fish was empty and one

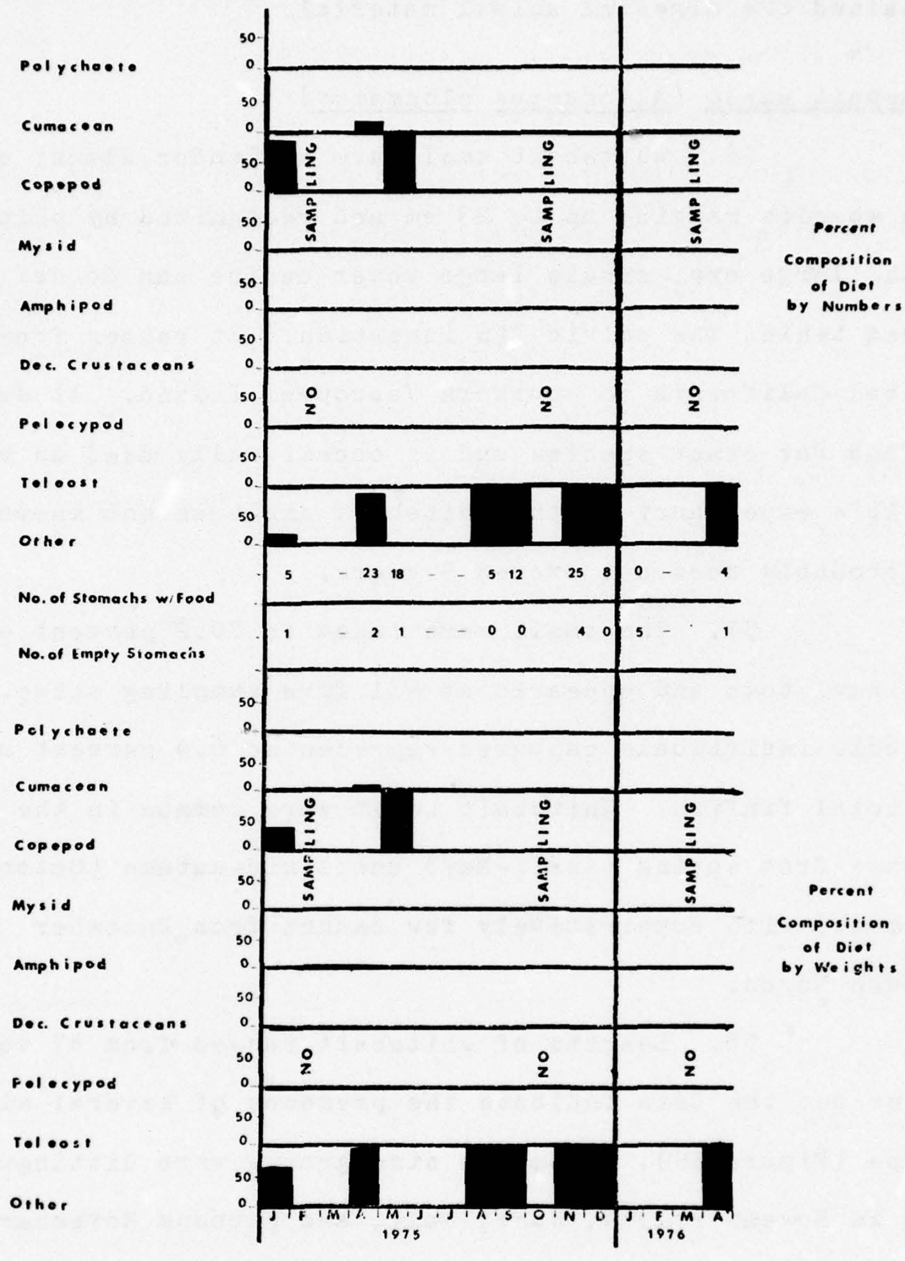

Figure E8. Monthly comparisons of northern anchovy expressed as percent composition of diet by numbers and weight, January 1975 through April 1976.

contained the digested animal material.

Whitebait smelt (Allosmerus elongatus)

56. Whitebait smelt are a slender almost colorless species ranging up to 23 cm and recognized by pointed mouth, large eye, single large vomer canine and dorsal fin placed behind the pelvic fin insertion. It ranges from central California to southern Vancouver Island. It serves as food for other species and is occasionally used as bait. The life expectancy of the whitebait smelt is not known but probably does not exceed 5 years.

57. The smelt were taken in 70.2 percent of the trawl tows and appeared at all five sampling sites. The 6010 individuals captured represented 6.9 percent of the total finfish. Whitebait smelt were common in the trawl catches from spring (April-May) until mid-autumn (October-November) with comparatively few caught from December through March.

58. Lengths of whitebait ranged from 47 to 145 mm and the data indicate the presence of several size groups (Figure E9). Separate size groups were distinguishable in November 1974, June, July, and perhaps November 1975, but thereafter size overlap obscured any length-frequency separation. It is apparent that juveniles and adults were found together. The smaller size groups of whitebait smelt first appeared in May 1975 and April 1976

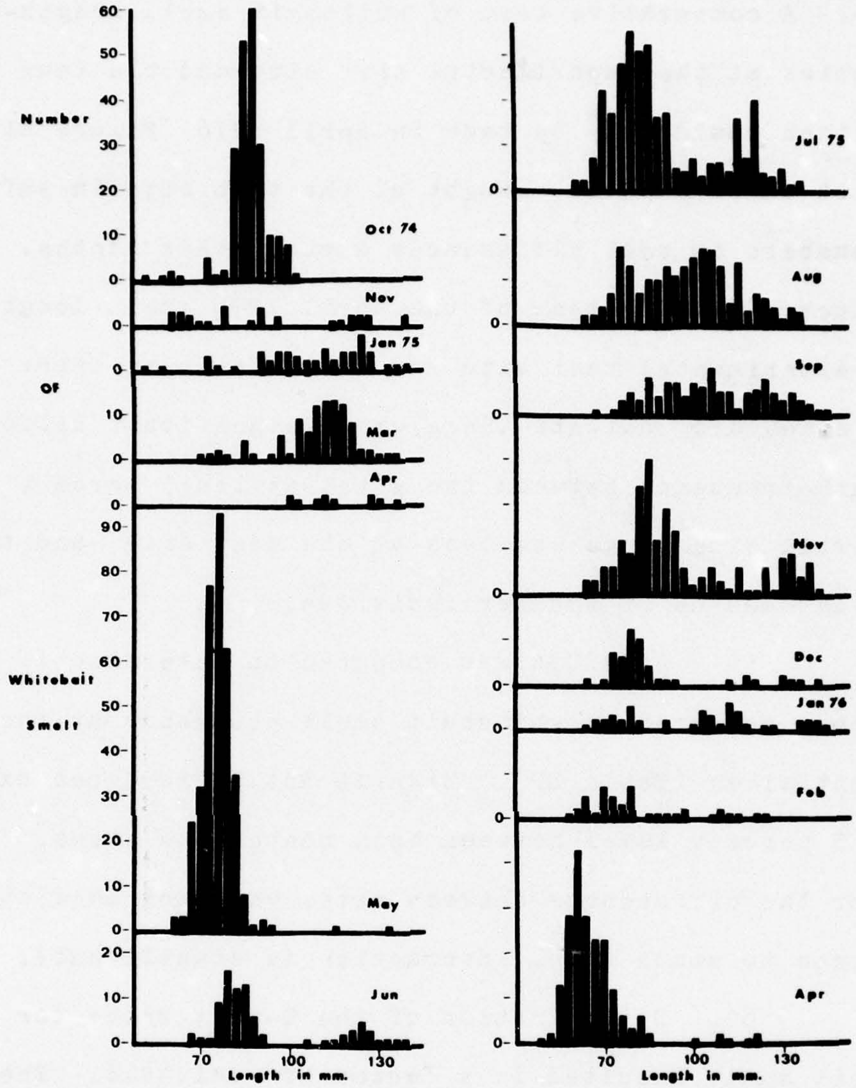

Figure E9. Monthly length-frequency histograms of whitebait smelt (Allosmerus elongatus) captured with trawl gear between October 1974 and April 1976.

catches. A comparative test of whitebait smelt length-frequencies at the experimental test site and the four other sites could only be made in April 1976 (Figure E10). Whitebait smelt were not caught at the test site in sufficient numbers to test differences during other months. A Kolmogorov-Smirnov test of the April 1976 smelt lengths at the experimental test site and those taken at other sample sites did indicate there was a significant difference in length-frequency between the sites at the 5 percent level. The overall size range was less at the test site, and the catch was made up of smaller individuals.

59. An ANOVA was computed to determine if a difference occurred in whitebait smelt abundance at the different sites (Table E2). Significant differences existed at the 5 percent level between both months and sites. Moreover the differences between sites were not consistent from month to month (i.e. interaction is significant).

60. Determination of the Q-test value for whitebait smelt resulted in a factor of z=1.4416. The site alignment based on significant relationship follows.

LARGEST MEAN ______________________ SMALLEST MEAN

Site	Site	Site	Site	Site
A	B	C	D	E
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
3.4200	2.6563	1.4688	1.0475	0.9838

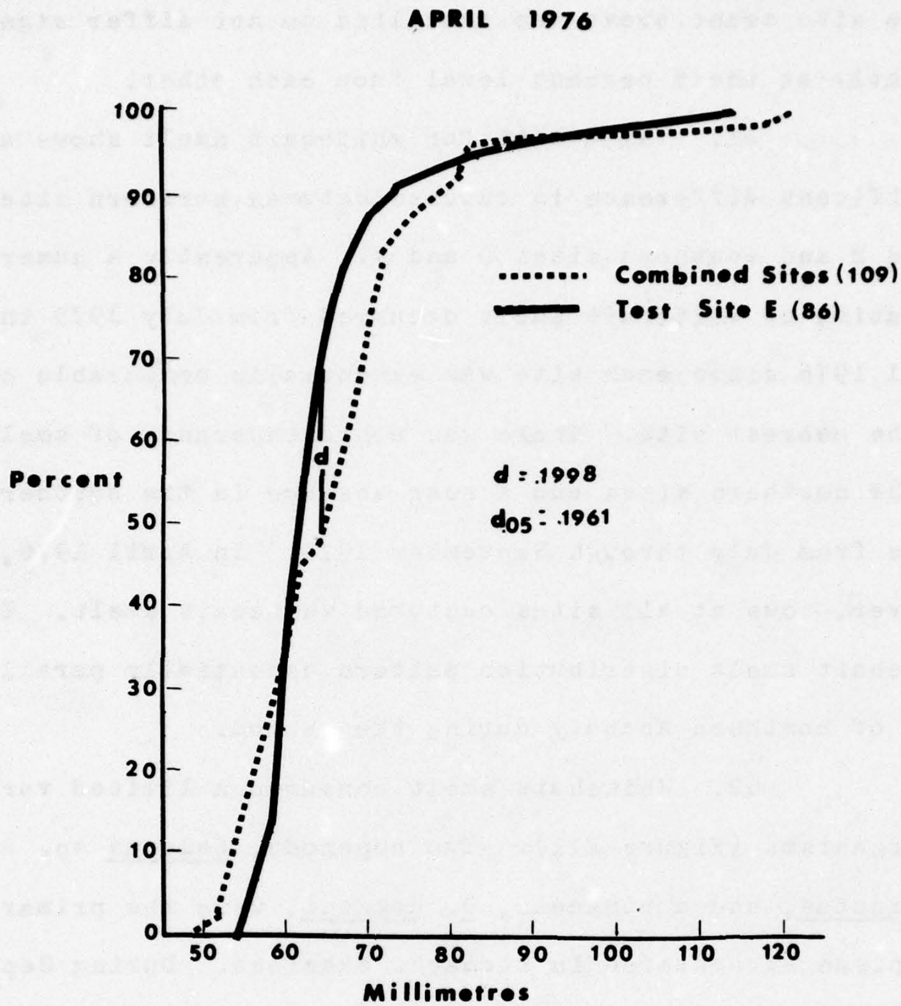

Figure E10. Comparative length-frequency of whitebait smelt (Allosmerus elongatus) captured with trawl nets.

Those site means above the same line do not differ significantly at the 5 percent level from each other.

61. The Q-test for whitebait smelt shows a significant difference in catches between northern sites A and B and southern sites D and E. Apparently a numerical gradation of whitebait smelt occurred from July 1975 through April 1976 since each site was essentially comparable only to the nearest site. There was a preponderance of smelt in the northern sites and a near absence in the southern sites from July through September 1975. In April 1976, however, tows at all sites captured whitebait smelt. The whitebait smelt distribution pattern essentially paralleled that of northern anchovy during the period.

62. Whitebait smelt consumed a limited variety of organisms (Figure E11). Two copepods, *Calanus* sp. and *P. minutus*, and a cumacean, *D. dawsoni*, were the primary organisms encountered in stomachs examined. During September 1975, the amphipod, *Atylus tridens*, and mysid, *Neomysis kadiakensis*, were eaten. Teleosts were important food items in the winter and those consumed were anchovies, *E. mordax*, and an unidentified, partially digested species.

63. The stomach contents were similar numerically and gravimetrically except for January 1975, when *Calanus* sp. was important in weight. The following additional food items were consumed at least once:

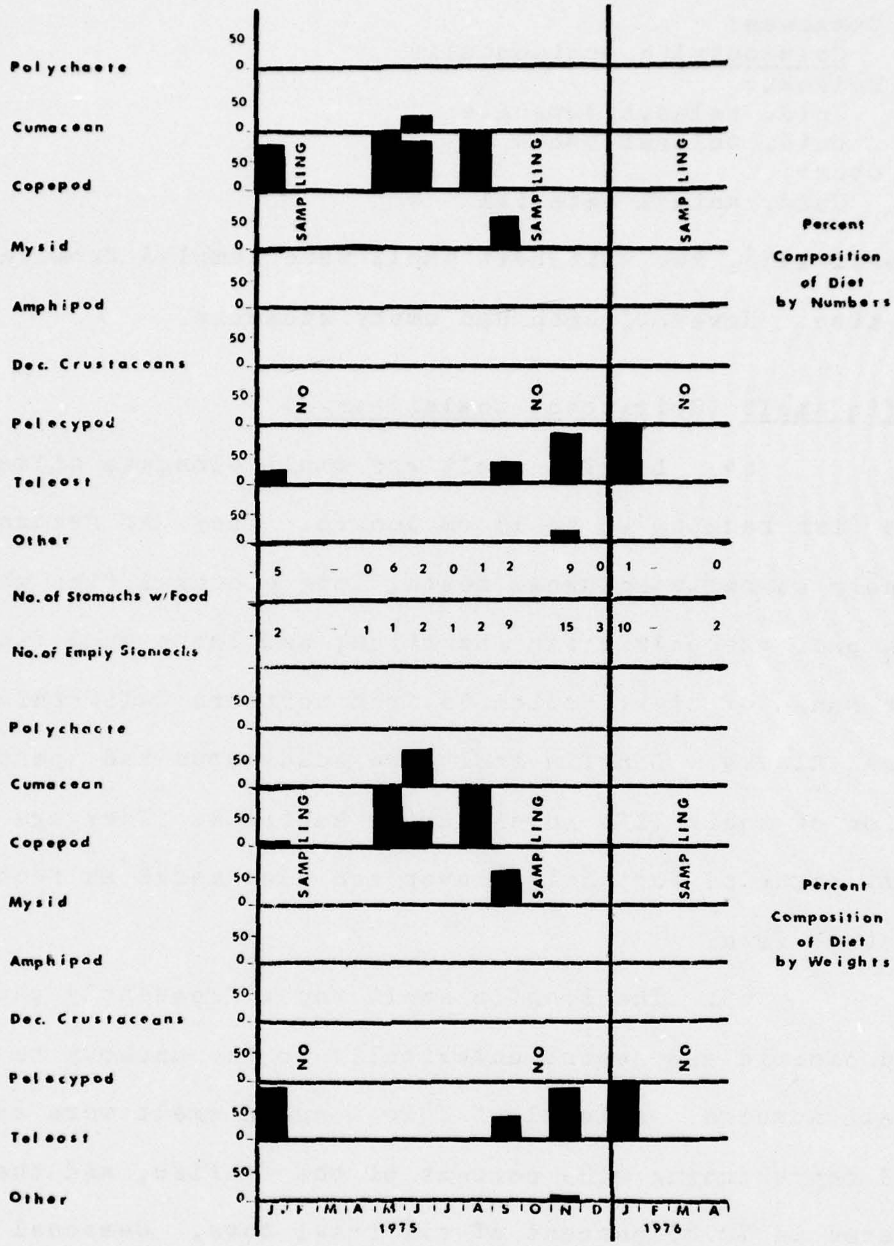

Figure E11. Monthly comparisons of whitebait smelt expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

Cumacean:
  Colurostylis occidentalis
Teleost:
  Unid. teleost juvenile
  Unid. teleost bones
Other:
  Unid. animal material

In April 1976, two whitebait smelt were sampled from the test site. However, both had empty stomachs.

Longfin smelt (*Spirinchus thaleichthys*)

64. Longfin smelt are small elongate silvery-white fish ranging up to 15 cm length. They are recognized by their strongly upturned mouth, long pectoral fins which reach past the pelvic fin insertion, and large anal fin. Their range of distribution is from northern California to central Alaska. Longfin smelt are anadromous and spend a portion of their life in estuarine habitats. They are highly regarded for their flavor and also serve as food for other fish.

65. The longfin smelt was a frequently captured osmerid and second numerically to the anchovy in overall numbers. A total of 7816 longfin smelt were captured representing 8.99 percent of the finfish, and they appeared in 72.85 percent of all trawl tows. Seasonal variation was indicated since longfin smelt were frequently caught in winter and spring while few were caught in early summer. Thereafter the trawl catches of longfin smelt increased gradually and, except for their near absence in

December 1975, were common through the remainder of the study.

66. The lengths of longfin smelt ranged from 43 to 135 mm. Size groups were obscured by overlap in most months, but it appeared that young fish were most abundant (Figure E12). Age 0 fish entered the trawl catch in July and August 1975 and merged with older fish by the following January. Length-frequency comparisons of smelt at the experimental test site and the other sites could only be made in April 1976 (Figure E13). A Kolmogorov-Smirnov two-sample test indicated a critical value of 0.2163, or no significant difference in longfin smelt length-frequency between the sites at the 5 percent level. There was, however, a difference at the 10 percent level. The comparisons of longfin smelt data by numbers caught at different months and locations are shown in Table E2.

67. An ANOVA in longfin smelt catches was calculated in order to determine if differences existed between sites and months (Table E2). It was determined that significant differences existed between catches at the five sites and months. The differences in catches between sites were not consistent from month to month as indicated by the significant interaction. The test substantiated the observations that longfin smelt catches were low in July 1975 and increased thereafter and that spatial differences occurred.

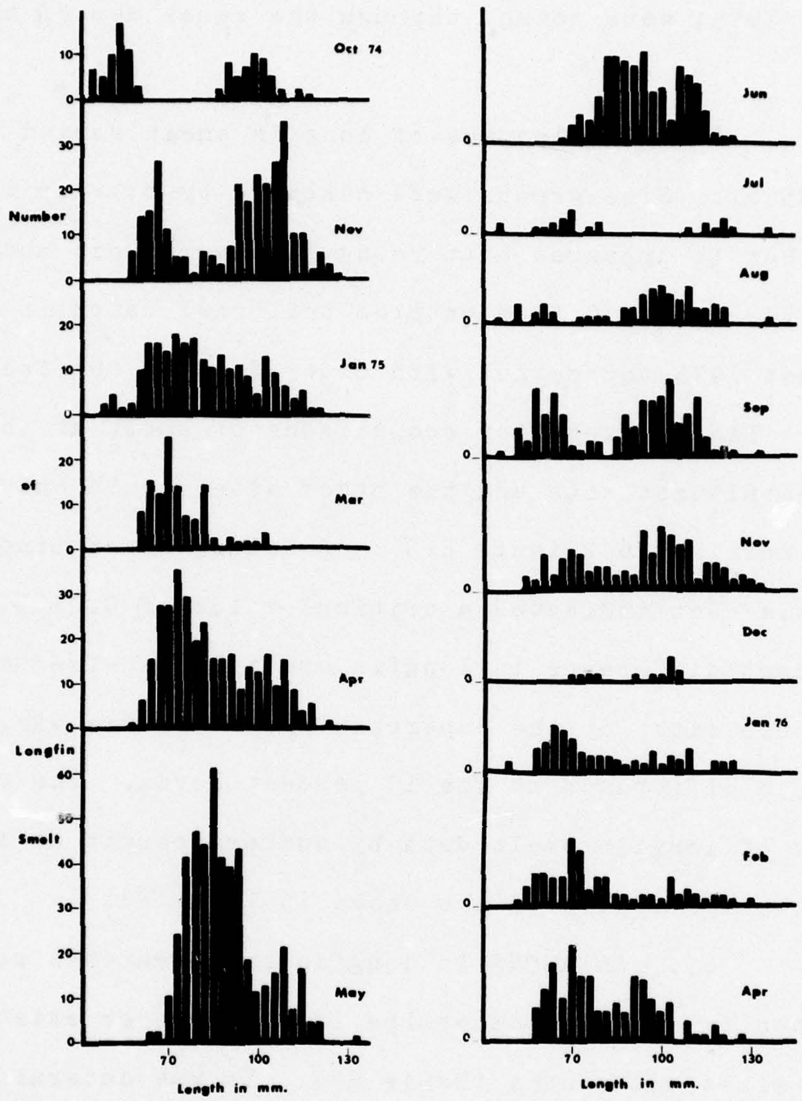

Figure E12. A monthly length-frequency histogram of longfin smelt (Spirinchus thaleichthys) between October 1974 and April 1976.

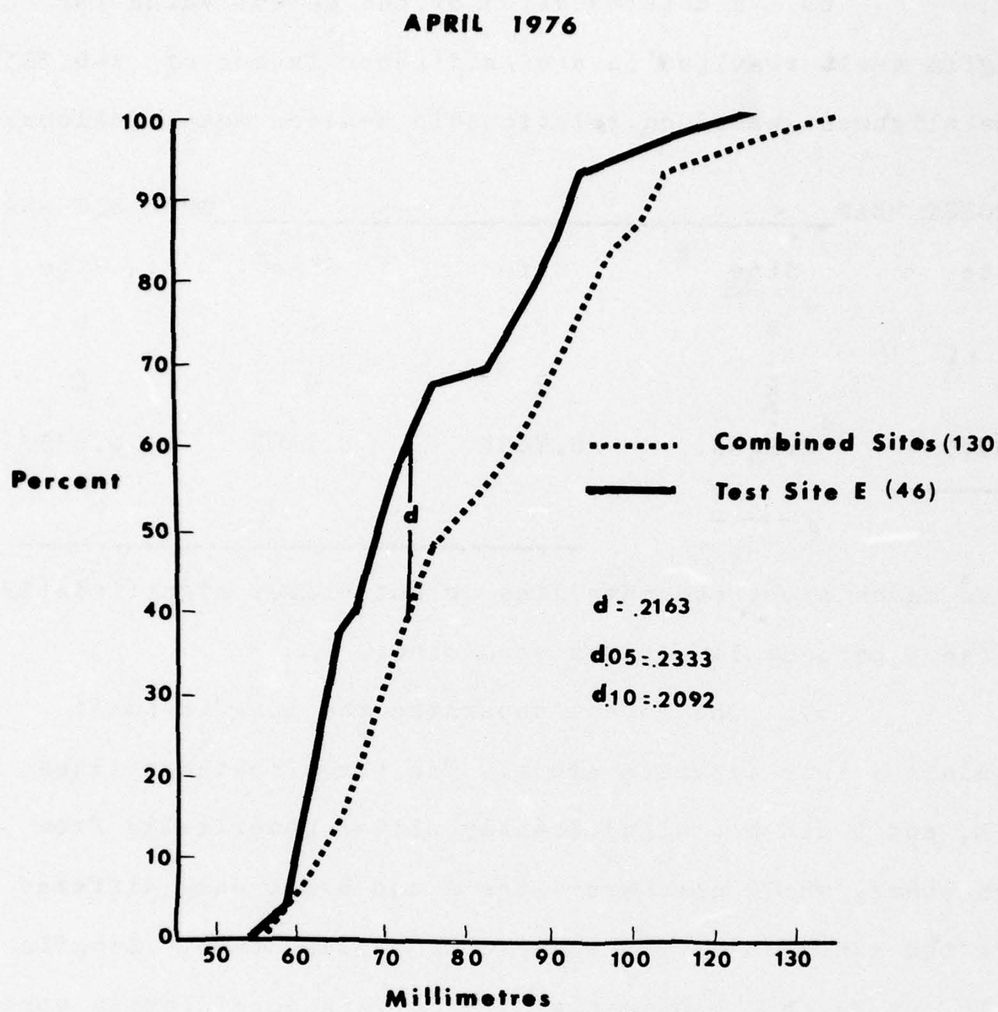

Figure E13. A comparative test of the cumulative percent of longfin smelt lengths (<u>Spirinchus thaleichthys</u>) captured during April 1976.

68. A determination of the Q-test value for longfin smelt resulted in a significance factor of $z=0.3151$. Site alignment based on relationship between means follows.

LARGEST MEAN ________________________ SMALLEST MEAN

Site	Site	Site	Site	Site
A	B	E	C	D
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
2.6075	2.2288	0.7838	0.7463	0.6550

Those means above the same line do not differ significantly at the 5 percent level from each other.

69. The Q-test separated the longfin smelt population into separate areas. The three southern sites C, E, and D did not significantly differ numerically from each other, while northern sites A and B not only differed from the southern sites but also from each other. Longfin smelt during this comparative period were consistently more numerous at sites A and B. Longfin smelt were not taken in the comparative trawl catches at the test site until April 1976.

70. Longfin smelt consumed small crustaceans found in the epibenthic and pelagic zones (Figure E14). The three major groups were cumaceans, copepods, and mysids. Analyzed by numbers, differences occur that may be seasonal trends. It was observed that each month, large numbers of

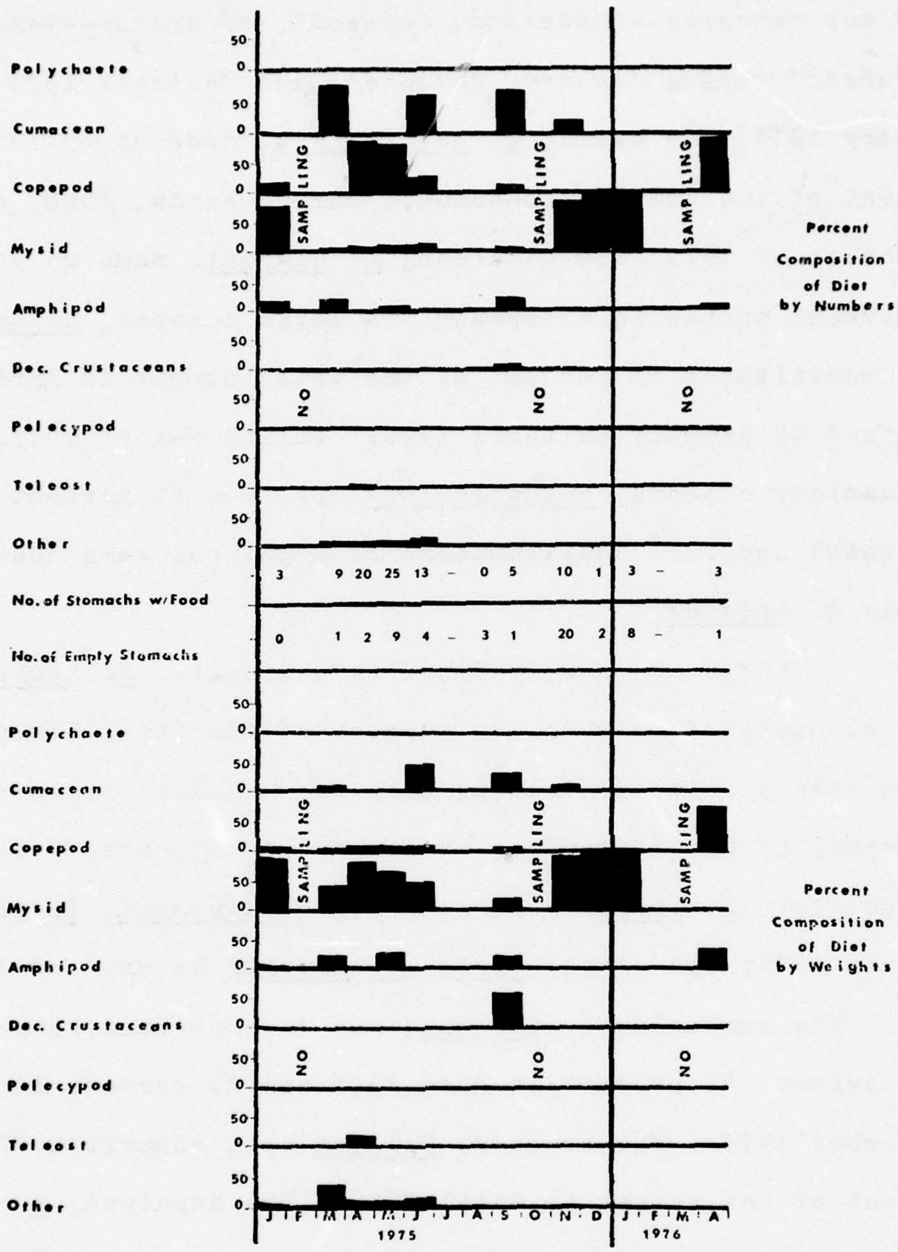

Figure E14. Monthly comparisons of longfin smelt expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

only one category--cumaceans, copepods, or mysids--were consumed. During January, November, and December 1975 and January 1976, the mysid, N. kadiakensis, made up 83-100 percent of the numbers consumed. During March, June, and September of 1975, the cumacean, D. dawsoni, made up 58-76 percent of the total number. A large copepod, Calanus sp., constituted 66 percent of the total number in April 1975 and 95 percent in April 1976. During May of 1975, the smaller copepod, Pseudocalanus sp., was 80 percent of the total number. Small numbers of amphipods were consumed, mainly A. tridens.

71. On a weight basis, the mysid, N. kadiakensis, accounted for 10 to 100 percent of the total during all months except April 1976, with the highest percentages occurring in winter months. Other mysids appeared less frequently: N. rayii in April 1975; Acanthomysis davisi in June 1975; and Archaeomysis grebnitzkii in May and June 1975. The cumacean, D. dawsoni, was an important weight item twice: 45 percent in June 1975 and 25 percent in September 1975. The copepod, Calanus sp., comprised 76 percent of the weight in April 1976. The amphipod, A. tridens, represented less than 25 percent of the weight in March, May, and September of 1975 and April 1976. During September 1975, a Crangon sp. juvenile made up 50 percent of the weight.

72. To briefly summarize, longfin smelt consumed

four items during the sample months. These were, in order of importance, the mysid, N. kadiakensis; copepods, Calanus sp. and P. minutus; and the cumacean, D. dawsoni. Seasonal patterns were not evident when the prey items were analyzed by weight. However, numerically, analysis revealed mysids were most important prey items for longfin smelt in winter months, being replaced by cumaceans and copepods in betw-- The widest variety of food items were consumed during the spring months. The following additional food items were consumed at least once:

Polychaete:
  Unidentified sp.
Cumacean:
  Mesolamprops sp.
Copepod:
  Unidentified sp.
Amphipod:
  Monoculodes sp.
Decapod Crustacean:
  Crangon sp. adult
Pelecypod:
  Pelecypod juveniles
Other:
  Synidotea angulata- (isopod)
  Organic material

73. Longfin smelt were sampled at the experimental site in April of 1976. Their diet consisted primarily of the copepod, Calanus sp., which accounted for 93 percent of the total number of organisms consumed and 76 percent of the total weight. An amphipod, A. tridens, contributed 23 percent of the total weight. Several other organisms were consumed in very small quantity: unidentified eggs; an unidentified mysid; and a small Mesolamprops sp.

Pacific tomcod (Microgadus proximus)

74. Pacific tomcod are round elongate fish, olive to light brown in color and ranging up to 33 cm total

length. They are recognized by small cycloid scales, three spineless dorsal fins, small centrally located barbel, and location of anus under the first dorsal fin. Tomcod are distributed from central California to the Bering Sea and are common in shallow water and estuaries. It is highly regarded for its food and recreational value. Its comparatively small size has limited commercial exploitation.

75. Pacific tomcod was one of two Gadidae species captured at the sampling sites. Pacific hake, the other species, was a summer visitor and was taken sporadically. Tomcod appeared in 76.16 percent of the trawl tows. During the study, 3305 tomcod were captured representing 3.8 percent of the total finfish caught. Tomcod were captured in all months sampled but were less frequently taken from mid-winter to late spring. Tomcod were common from August to November.

76. Pacific tomcod lengths ranged from 27 to 300 mm during the study period. The population consisted of two distinct size groups through July 1975 and one size group thereafter. Size classes were separate and more distinctive than those of other species (Figure E15). Tomcod lengths from the experimental site were not compared with those at the other sites because insufficient numbers were taken at the test site.

77. Results from an ANOVA for Pacific tomcod by site and month are presented in Table E2. Significant

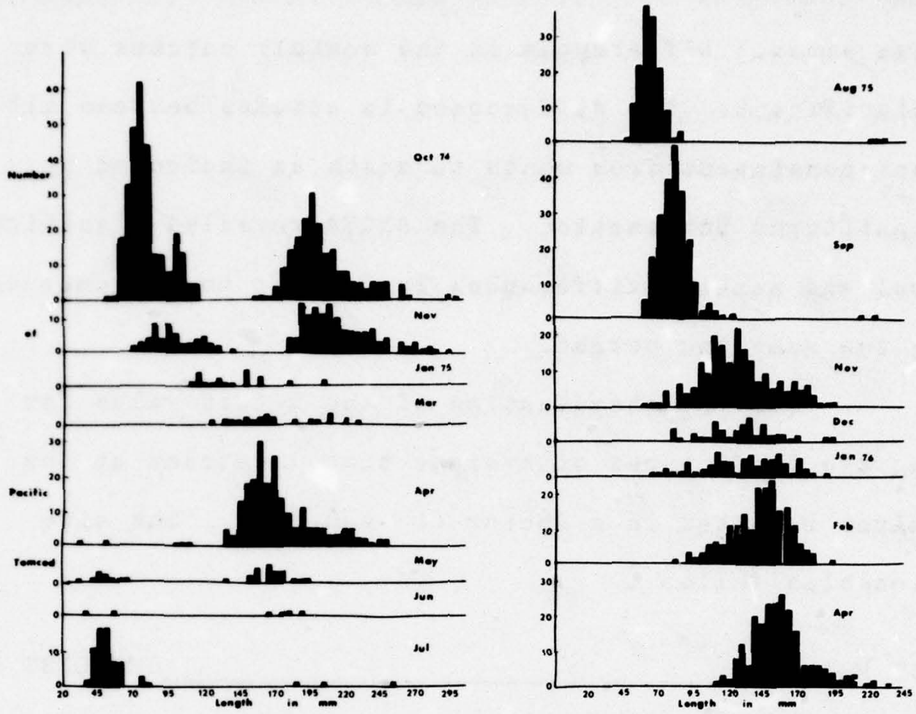

Figure E15. Monthly length-frequency histogram of Pacific tomcod (Microgadus proximus) from October 1974 to April 1976.

differences existed between the numbers of tomcod caught at the five sites. Differences in the monthly catches were also significant. The differences in catches between sites were not consistent from month to month as indicated by the significant interaction. The ANOVA revealed significant temporal and spatial differences in Pacific tomcod catches during the sampling period.

78. A determination of the Q-test value for testing the differences of average tomcod catches at the five sites resulted in a factor of z=0.8008. The site relationships follow .

LARGEST MEAN ______ SMALLEST MEAN

Site	Site	Site	Site	Site
B	A	C	E	D
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
3.2988	3.2338	1.2525	1.1363	0.5700

Those site mean catches above the same line do not differ significantly at the 5 percent level from each other.

79. The Q-test indicates there was no significant difference in catches of tomcod between the two northern sites A and B. Catches at the three southern sites C, D, and E also were not significantly different. The differences in tomcod catches between northern and southern sites, however, were significant. The tests confirmed the

seasonal changes in availability of tomcod and further reflected differences in catches between the sampling sites.

80. Pacific tomcod consumed items from all major groups of food organisms (Figure E16). Polychaete worms were eaten but not in quantity. Analyzed numerically, fewer groups were consumed in the spring and summer than during fall and winter. The cumacean, D. dawsoni, made up 94 percent of the total number of organisms in April of 1975; 87 percent in May 1975; 99 percent in September 1975; and 20 percent in November 1975. Mesolamprops sp. contributed 91 percent in April of 1976. Crangon sp. made up 23 percent of the total in January of 1975 and 14 percent in July 1975. However, they were important food items in November and December of 1975 and January and February of 1976 with percentages of 28, 45, 31, and 21, respectively. Northern anchovy, E. mordax, was consumed in January and December of 1975 and in January and February of 1976. The remaining food consumption pattern was scattered. During January 1975, the amphipod, A. tridens, made up 41 percent of the total; and in July of 1975, the copepod, Calanus sp., made up 43 percent.

81. Analyzed gravimetrically, a more definite pattern was observed. Just four categories represented any weight significance: cumaceans, decapod crustaceans, teleosts, and other (mainly detritus). The cumacean, D. dawsoni, made up less than 15 percent of the total in

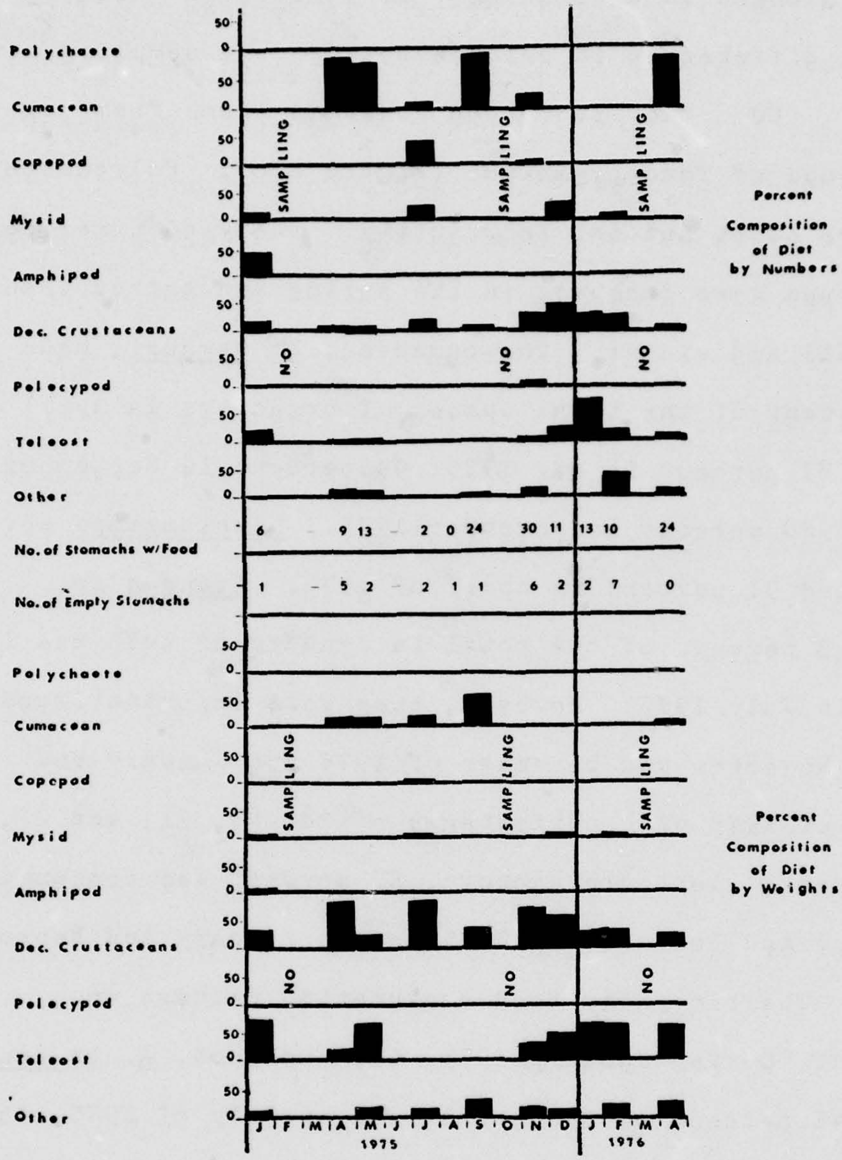

Figure E16. Monthly comparisons of Pacific tom-cod expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

April and May 1975, but 51 percent in September 1975. In July 1975, the cumacean, _C. occidentalis_, was eaten; and in April 1976, _Mesolamprops_ sp. Decapod crustaceans (in this case crangonids) and fish were preyed upon throughout the year. Adult _Crangon_ sp. made up 21 percent of the total weight in January 1975; 77 percent in April; 19 percent in May; 78 percent in July; 43 percent in November; and 43 percent in December 1975; and less than 25 percent in January, February, and April 1976. Juvenile _Crangon_ sp. made up 25 percent or less of the total in September and November 1975. The anchovy, _E. mordax_, made up 62 percent of the total weight in January 1975; 9 percent in April; 57 percent in May; 22 percent in November; 50 percent in December 1975; 84 percent in January 1976; 60 percent in February; and 53 percent in April 1976. Rockfish juveniles made up less than 5 percent of the total weight in May and November 1975.

82. In summary, three groups of food items were particularly important to the Pacific tomcod: the cumacean, _D. dawsoni_; shrimp, _Crangon_ sp., juveniles and adults; and the northern anchovy, _E. mordax_. Numerically, _D. dawsoni_ outranked other food items. Gravimetrically, however, the shrimp and anchovy dominate food items except in April 1975, when the cumacean, _D. dawsoni_, outweighed the others. Adult or juvenile shrimp occurred in all months when full stomachs were sampled. The only seasonal trend

noted was that anchovy did not appear in Pacific tomcod stomachs between June and September 1975. Casual observation indicated a tomcod would either consume large numbers of small organisms, such as cumaceans, or a few large items, such as shrimp or anchovies. The following additional prey items were consumed at least once:

Polychaete:
- Unidentified polychaete
- *Nereis* sp.

Mysid:
- *Neomysis kadiakensis*
- *Neomysis rayii*
- *Acanthomysis nephrophthalma*

Amphipod:
- *Monoculodes* sp.
- *Hippomedon denticulatus*
- *Ampelisca macrocephala*
- *Synchelidium* sp.
- *Paraphoxus obtusidens*

Decapod Crustaceans:
- *Cancer magister* juv.

Pelecypod:
- Unident. pelecypod
- *Siliqua patula* siphons

Other:
- *Tecticeps* sp. (isopod)
- *Synidotea angulata*- (isopod)
- Animal debris
- Vegetable debris

83. Pacific tomcod were sampled at the experimental site in July of 1975 and February and April of 1976 (Figure E17). Analyzed by numbers, the predisposal stomach samples from July 1975 showed a diet of 43 percent copepods, *Calanus* sp.; 29 percent mysids, *Neomysis kadiakensis*; and 14 percent each of shrimp juveniles, *Crangon* sp., and cumaceans, *Colurostylis occidentalis*. Shrimp, *Crangon* sp., contributed 37 percent of the total number in February and 29 percent in April 1976. The northern anchovy, *E. mordax*, made up 25 percent of the total number in February 1976.

84. Analyzed by weights, shrimp were the most important food item. *Crangon* sp. made up 78 percent of the

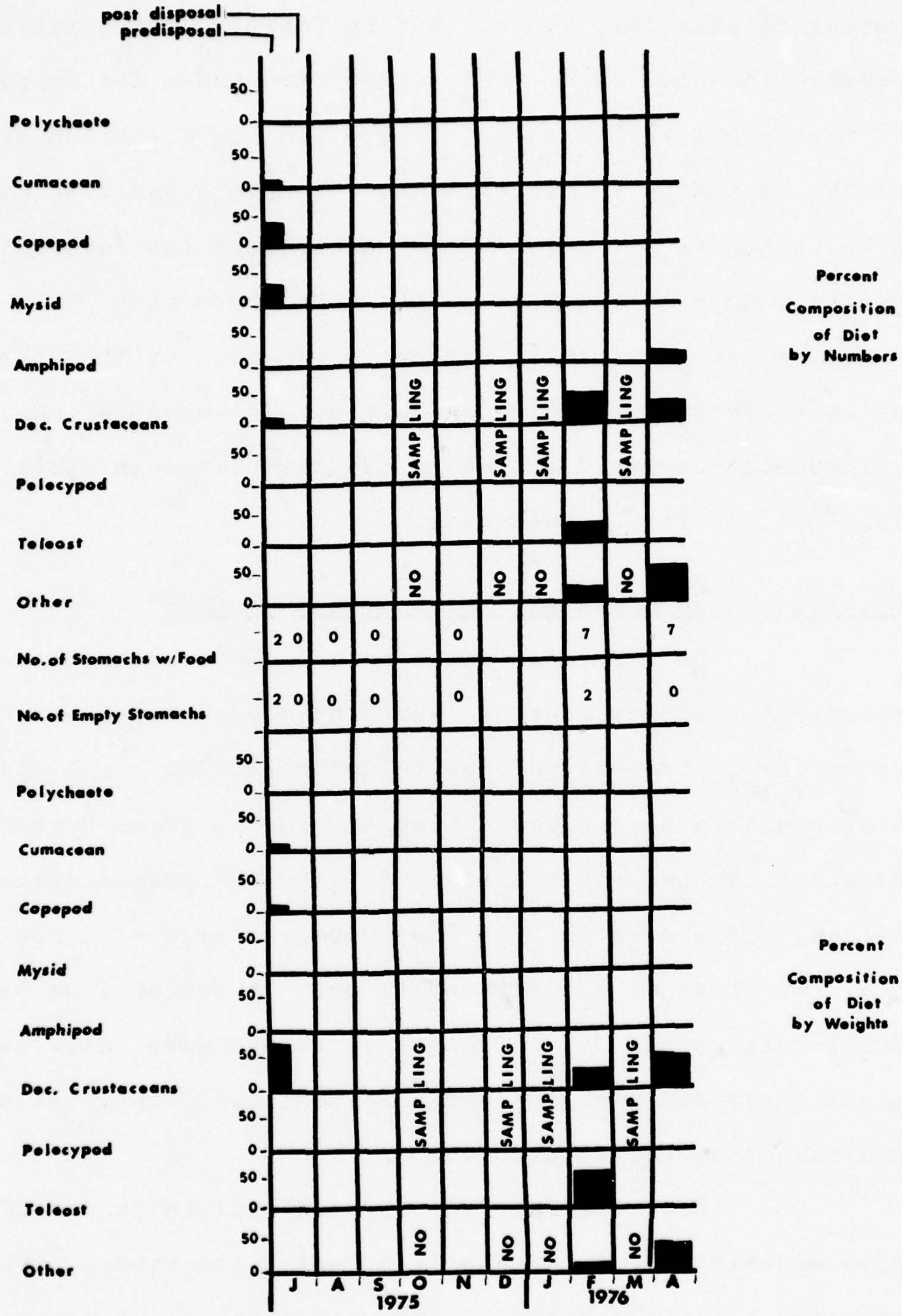

Figure E17. Monthly comparisons of Pacific tomcod from the test site expressed as percent composition of diet by numbers and weights, July 1975 through April 1976.

weight in July 1975, 23 percent in February 1976, and 62 percent in April 1976. The anchovy accounted for 66 percent of the weight in February. Figure E18 shows the comparisons of the test site to the other four sample sites from July 1975 through April 1976. Fish captured at the test site consumed more shrimp than at the other four sites in February and April 1976, and more fish than at the other sites in February 1976. Consumption of cumaceans and polychaetes occurred at two of the five sites in April 1976 but not at the test site.

Pacific staghorn sculpin (*Leptocottus armatus*)

85. Pacific staghorn sculpin are a common efficient predator species, associated with coastal and estuarine bottom communities to depths of 100 m. It is distinguished by its large head and mouth, green barred markings on the body and fins, antler-like preopercular spines, and a dark spot on the posterior part of dorsal fin. It grows to a length of 32 cm. It ranges from Baja California to the Gulf of Alaska. It has some value as a scavenger and predator and a recreational fish. It also provides food for waterfowl.

86. The Pacific staghorn sculpin is one of five species of cottids captured during the study. The staghorn sculpin appeared in 48.3 percent of the tows though the numerical total catch of 282 (0.3 percent) individuals

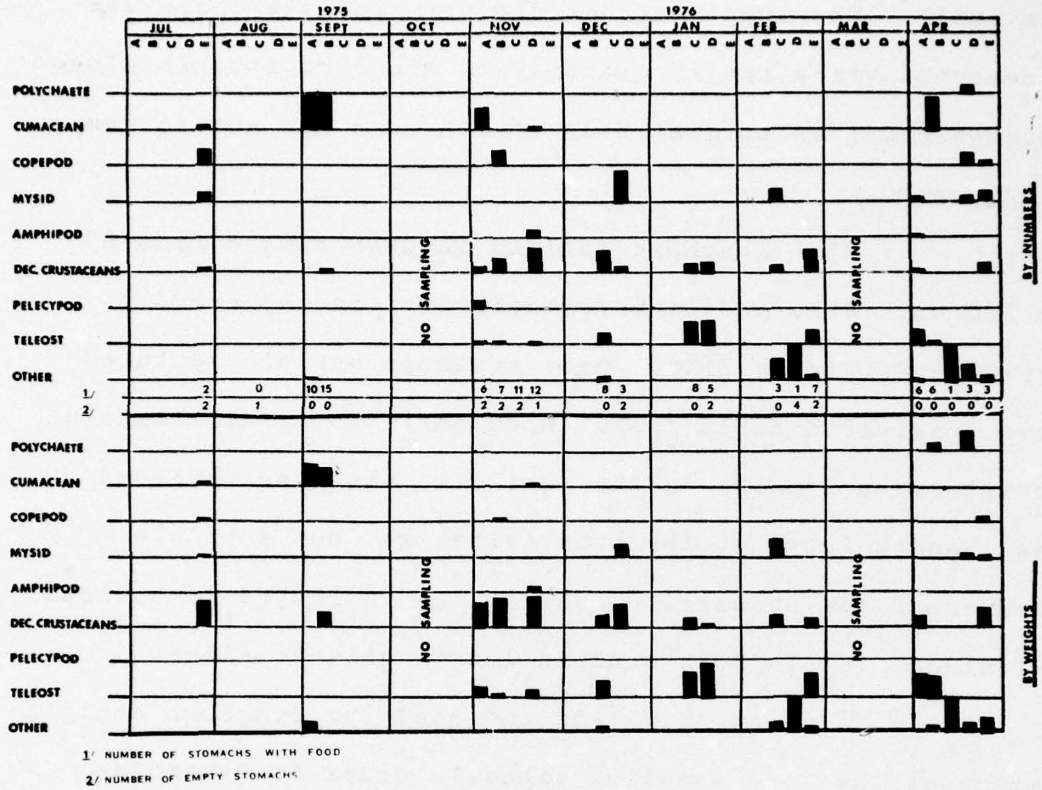

Figure E18. Comparison of five sampling sites, by month, for Pacific tomcod expressed as percent composition of diet by numbers and weights, July 1975 through April 1976.

was small. The trawl catches did not indicate there was a seasonal variation in quantity of staghorn sculpin since catches remained consistently low through the entire sampling period.

87. Staghorn sculpin lengths ranged from 65 to 260 mm. Size groups were indistinct and apparently overlapped (Figure E19). Most staghorn sculpin captured were considered adult fish. A comparison of the staghorn sculpin mean lengths at the test site with the combined mean length found at the other sites was not possible because of low numbers. Observations indicated no obvious difference in staghorn sculpin length between sites.

88. An ANOVA was computed for staghorn sculpin caught at the five sampling sites in order to determine the monthly and site changes (Table E2). The ANOVA test showed significant differences in staghorn catches between sites and between months. Also the differences between sites were not consistent from one month to the next as indicated by the significant interaction. Small scattered catches were characteristic of this species.

89. The Q-test of staghorn sculpin numbers resulted in a value of z=0.5840. Site relationship follows.

LARGEST MEAN ——— SMALLEST MEAN

Site E	Site C	Site A	Site B	Site D
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
0.8500	0.3612	0.3100	0.3100	0.2587

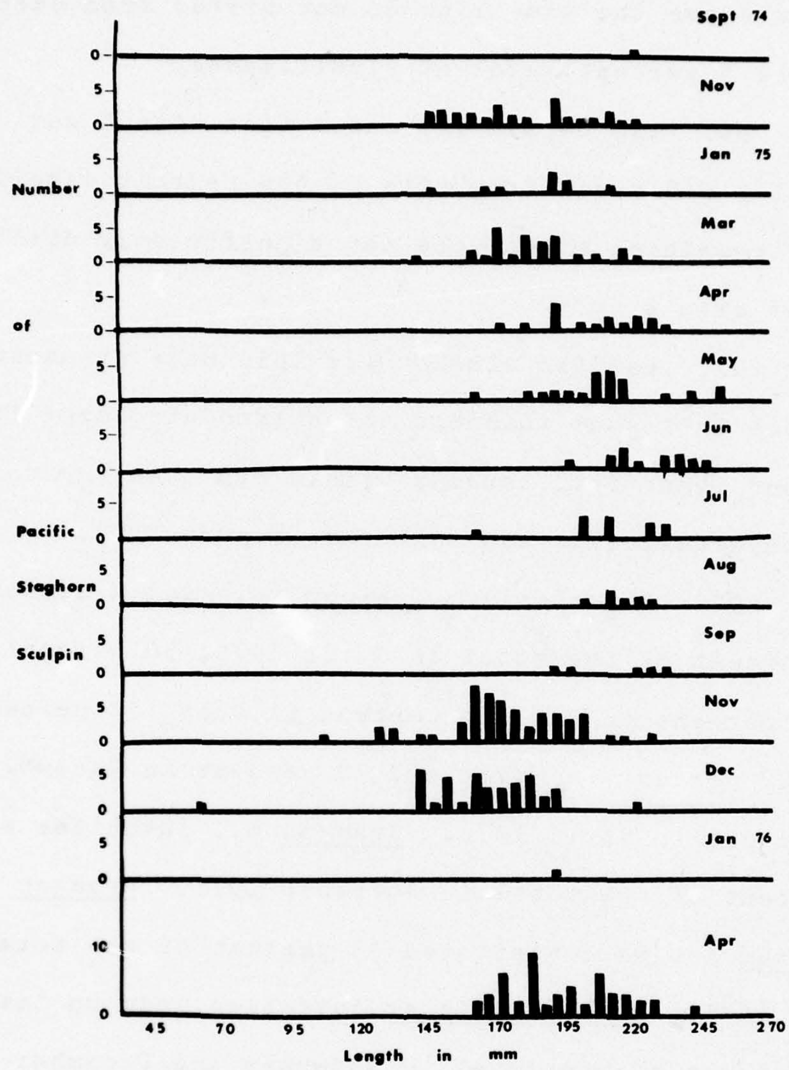

Figure E19. Monthly length-frequency histogram of Pacific staghorn sculpin (Leptocottus armatus) taken with an 8-m trawl net between October 1974 and April 1976.

Those means above the same line do not differ from each other at the 5 percent level of significance.

90. The Q-test indicates test site E was significantly different from site D, the nearest sampling site. The remaining sites were not significantly different from either site E or D.

91. Pacific staghorn sculpin have stomachs that stretch to tissue thinness to accommodate large food items. Food items fell usually within two major groups--the decapod crustaceans and teleosts (Figure E20).

92. Numerically, Crangon sp. adults accounted for 100 percent of the total in March 1975, 50 percent in April, 33 percent in May, 58 percent in June, 17 percent in July, 22 percent in November, 40 percent in December 1975, and 25 percent in April 1976. Crangon sp. juveniles made up 26 percent of the total in November 1975. Crangon franciscorum adults contributed 33 percent of the total in September 1975. Cancer magister juveniles made up less than 20 percent of the total in November and December 1975. The anchovy, E. mordax, accounted for 25 percent of the total number in April 1975, 50 percent in May, 25 percent in June, 55 percent in July 1975, and 69 percent in April 1976. Unidentified, partially digested fish contributed 33 percent in September 1975 and 50 percent in January 1976. The "other" category included some unidentified vegetation, isopods, and snails.

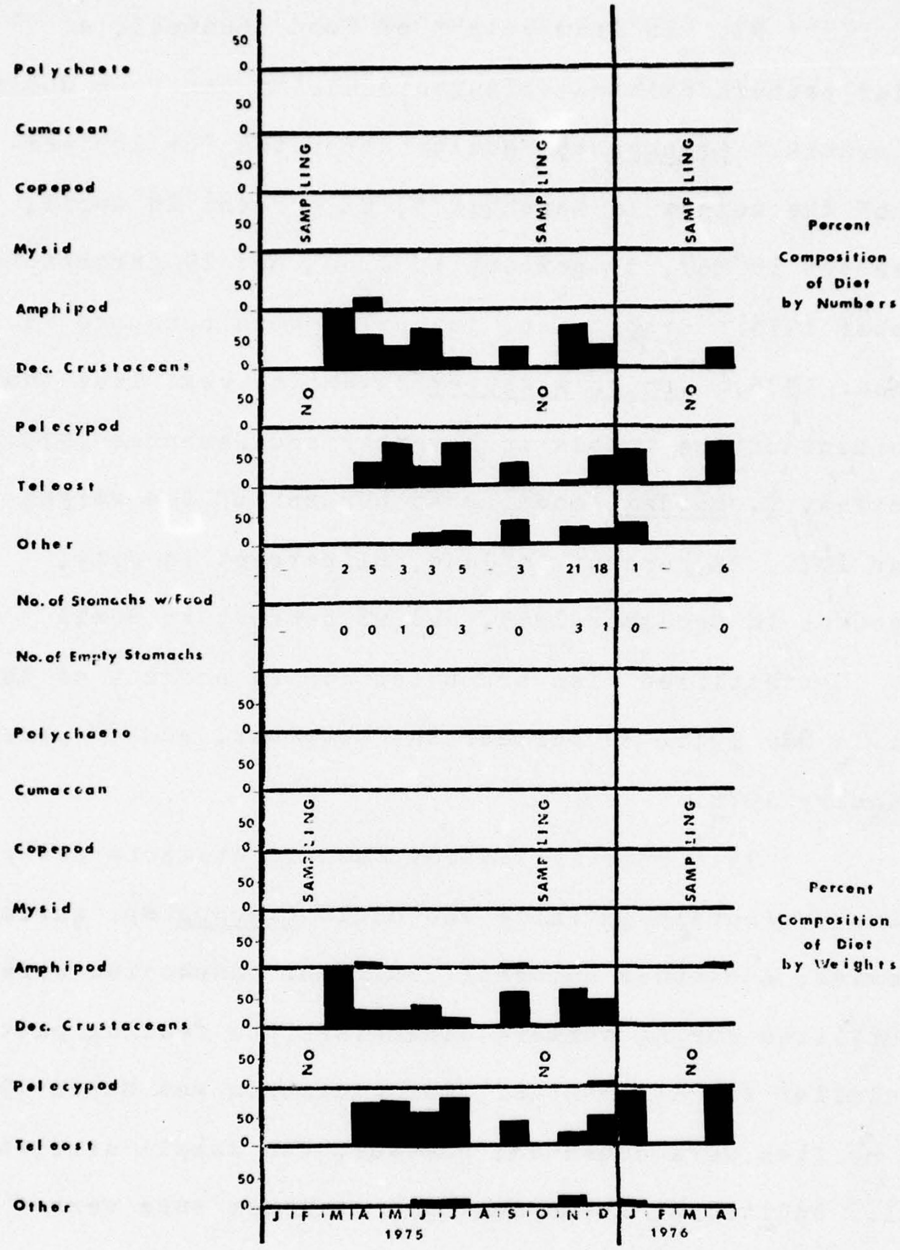

Figure E20. Monthly comparisons of Pacific staghorn sculpin expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

93. In gram weight of food consumed, a similar pattern existed--crangonid shrimp and fish during most months. *Crangon* sp. adults accounted for 100 percent of the weight in March 1975, 23 percent in April, 28 percent in May, 39 percent in June, and 29 percent in December 1975. *Crangon* sp. juveniles were consumed in November 1975. *Cancer magister* juveniles were less than 30 percent of the totals in November and December 1975. Anchovies, *E. mordax*, made up 45 percent of the weight in May 1975, 23 percent in June, 81 percent in July, 30 percent in December 1975, and 93 percent in April 1976. Unidentified fish accounted for 27 percent of the total in May 1975, 39 percent in September, and 88 percent in January 1976.

94. Briefly stated, Pacific staghorn sculpins consumed primarily juvenile and adult *Crangon* sp. shrimp, anchovies, and other unidentified fish. Anchovies were not utilized during summer; otherwise, the feeding pattern was similar for all months. One exception was March 1975, when no fish were consumed; however, the sample size was small. Additional items consumed at least once were:

Mysid:
- *Neomysis kadiakensis*
- *Acanthomysis macropsis*

Amphipod:
- *Atylus tridens*

Pelecypod:
- *Siliqua patula* juveniles

Teleost:
- *Sebastes* sp.
- *Microstomus pacificus* juv.

Other:
- Unident. fish eggs
- Unident. vegetation
- Unident. animal material
- *Tecticeps* sp. (isopod)
- *Nassarius* sp. (gastropod)

95. Staghorn sculpin were caught at the experimental site in July 1975 and April 1976. Shrimp, Crangon sp., and anchovies, E. mordax, were the two important food items. During July 1975, shrimp contributed 50 percent of the total numbers and weights and unidentified vegetation the other 50 percent. In April 1976, the shrimp made up 29 percent of the numbers and 8 percent of the weight while the anchovy accounted for 29 percent of the number and 84 percent of the weight.

Pricklebreast poacher (*Stellerina xyosterna*)

96. Pricklebreast poachers are small (to 18 cm) fish, rounded anteriorally and tapering to a narrow caudal. The coloring is a mottled olive dorsally and light ventrally. The distinguishing characteristic of this fish, found at depths of 15 to 76 m, is the smooth breast stippled with small spines. They are found from Baja California to British Columbia, although somewhat uncommon at the limits of their range. The pricklebreast poacher has neither recreational nor commercial value.

97. The pricklebreast poacher numerically dominated the five species of the Family Agonidae encountered. During the study 4098 pricklebreast poachers were captured, which represented 4.7 percent of all finfish taken. These small demersal fish occurred in 71.5 percent of the trawl tows. Some pricklebreast poachers were

present throughout the year, but they were not common from October 1975 through January 1976. The pricklebreast poachers were widely and commonly taken in the spring; however, the largest catches were in August and September 1975. At that time the sporadic large catches indicated schooling behavior.

98. Lengths of pricklebreast poachers ranged from 27 to 163 mm during the study period. Examination of a monthly length-frequency histogram (Figure E21) indicated several size groups were present and distinguishable for at least a year. A comparison of pricklebreast poacher lengths at the experimental site and those found at the other sites was not possible because few poachers were taken at the test site.

99. An ANOVA was made to determine the comparability of pricklebreast poacher catches at the five sampling sites (Table E2). The test revealed significant differences in the number of pricklebreast poacher caught at the five sites and between months. The significant interaction value indicated the catches between sites were not consistent from month to month. Periodic occurrence of schools of pricklebreast poacher at northern sites nullified any possible numerical relationship with southern sites.

100. A Q-test of the significant relationship between the catches at the sites resulted in a value of

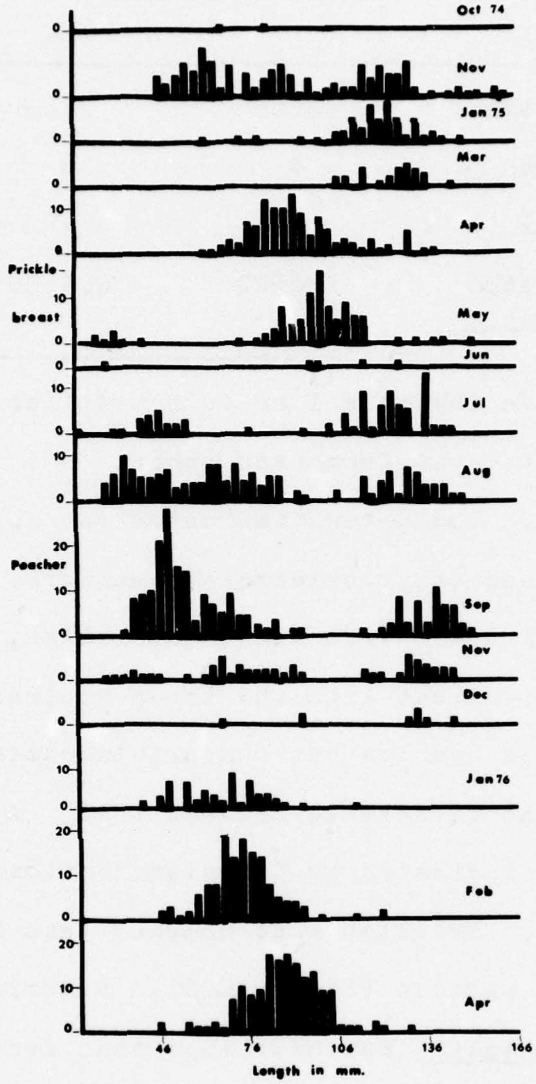

Figure E21. Monthly length-frequency histogram of the pricklebreast poacher (<u>Stellerina xyosterna</u>) taken with an 8-m trawl net.

z=1.6326. The site relationship follows:

LARGEST MEAN ________________________________ SMALLEST MEAN

Site	Site	Site	Site	Site
A	B	C	E	D
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
3.1500	3.1500	0.8800	0.4600	0.3500

Those means above the same line do not differ significantly at the 5 percent level from each other.

101. The Q-test indicated two separate distribution areas of pricklebreast poachers. Catches at northern sites A and B were high and similar, but were significantly different from the three southern sites. Sites C, D, and E had low but comparable catches, and there is no significant difference between them. A spatial availability is indicated by the distribution of catches.

102. Pricklebreast poacher data showed a limited feeding pattern (Figure E22). Numerically, the mysid, N. kadiakensis, was most important during all sample months except August 1975 and April 1976. This particular mysid accounted for 81 percent of the total number of organisms in January 1975, 41 percent in March, 57 percent in April, 46 percent in May, 25 percent in July, 48 percent in September, 93 percent in November, 100 percent in December 1975, 100 percent in January 1976, and 82 percent in February 1976. N. kadiakensis contributed

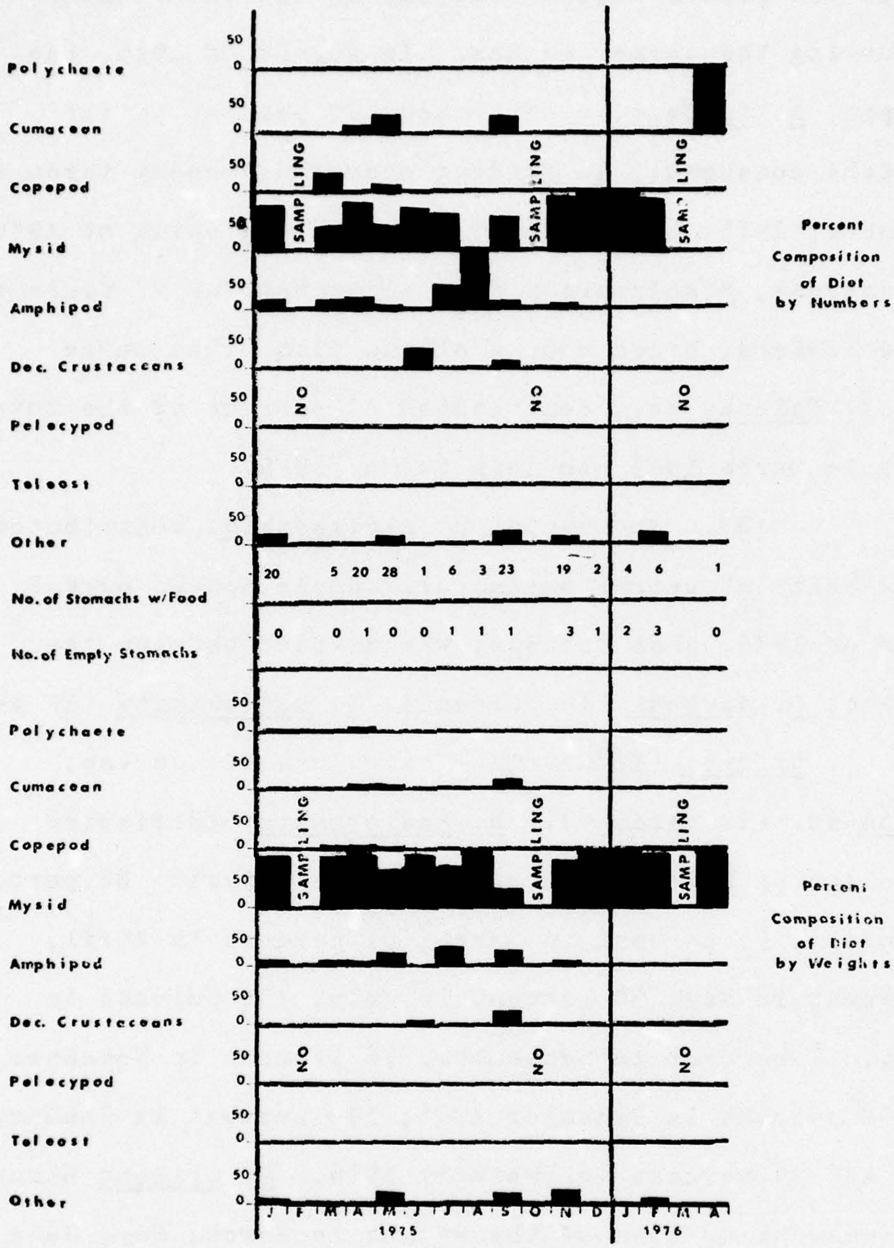

Figure E22. Monthly comparisons of pricklebreast poacher expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

more to the pricklebreast diet during the cold months than during the warmer months. In August of 1975, the amphipod, A. tridens, contributed 100 percent of the organisms consumed. A. tridens occurred January through September, 1975, but in lower numbers. In April of 1976, the cumacean, Mesolamprops sp., accounted for 97 percent of the numbers, based upon a single fish. The large copepod, Calanus sp., contributed 37 percent of the total number in March 1975 and less in May 1975.

103. The mysid, N. kadiakensis, contributed the majority of weight during all sample months except September 1975, when the diet was divided between the cumacean, D. dawsoni (15 percent), N. kadiakensis (32 percent), A. tridens (18 percent), and juvenile shrimp, Crangon sp. (19 percent). N. kadiakensis contributed the following percentages of the total weight: 88 percent in January, 86 percent in March, 81 percent in April, 61 percent in May, 30 percent in July, 100 percent in August, 32 percent in September, 76 percent in November, and 100 percent in December 1975; 100 percent in January 1976; and 94 percent in February 1976. A. tridens occurred as 30 percent or less of the weight in March, May, July, and September 1975.

104. In summary, the mysid, N. kadiakensis, was clearly the most important food item to pricklebreast poachers during the study months. The amphipod, A. tridens,

supplemented the mysid diet as did occasional other mysids, cumaceans, copepods, and juvenile shrimp. The mysid consumption pattern was fairly consistent through all seasons, though it dropped somewhat during the warmer months. It is reasonable to assume that pricklebreast poachers do not often, if at all, feed directly upon or within the substrate but rather feed on epibenthic or pelagic forms. Additional items consumed at least once were:

Copepod:
- *Eucalanus bungii*
- *Pseudocalanus minutus*
- *Epilabidocera* sp.

Mysid:
- *Acanthomysis davisi*
- *Acanthomysis macropsis*
- *Acanthomysis nephrophthalma*
- *Neomysis rayii*
- *Archaeomysis grebnitzkii*

Amphipod:
- Unident. amphipod
- *Ampelisca macrocephala*
- *Monoculodes* sp.
- *Elasmopus* sp.

Decapod Crustaceans:
- *Cancer* sp. juv.
- Decapod zoea

Other:
- *Tecticeps* sp. (isopod)
- *Synidotea angulata*- (isopod)
- Unident. organic matter

Showy snailfish (*Liparis pulchellus*)

105. Showy snailfish resemble large tadpoles (lengths to 25 cm) with subterminal mouths and thin, loose skin with no scales. The dorsal and anal fins are long and extend onto the caudal fin. It is light to dark brown dorsally, lighter ventrally, and wavy longitudinal dark lines are sometimes present. Ranging from California to the Bering Sea, it is quite common in its northern limit at depths of down to 60 m. The snailfish has no recreational or commercial value.

106. The showy snailfish was the single cyclopterid species captured during the study period though several are known to inhabit the area. A total of 2400 snailfish were captured representing 2.8 percent of all finfish. Their overall incidence of capture in the 151 trawl tows was 67.5 percent. Few showy snailfish appeared in trawl catches from October through December 1975. Peak catches were made in August and September 1975. This was the only temporal or seasonal characteristic observed.

107. Showy snailfish are a small demersal species that ranged in length from 18 to 214 mm at the study sites. A length-frequency histogram plotted by monthly periods indicated several size groups were present, but overlap tended to obscure size distinction and growth patterns (Figure E23). Apparently the youngest size groups entered the catch in April or May 1975. It was not possible to test snailfish lengths at experimental test site E with lengths at other sites. During those periods of equal fishing effort, few showy snailfish were taken at the test site.

108. An ANOVA for showy snailfish catches was made to compare the temporal and spatial differences of snailfish numbers (Table E2). The showy snailfish exhibited significant numerical differences among sites; the monthly catches did not differ significantly at the 5 percent level. Differences among sites appeared to be consistent from month

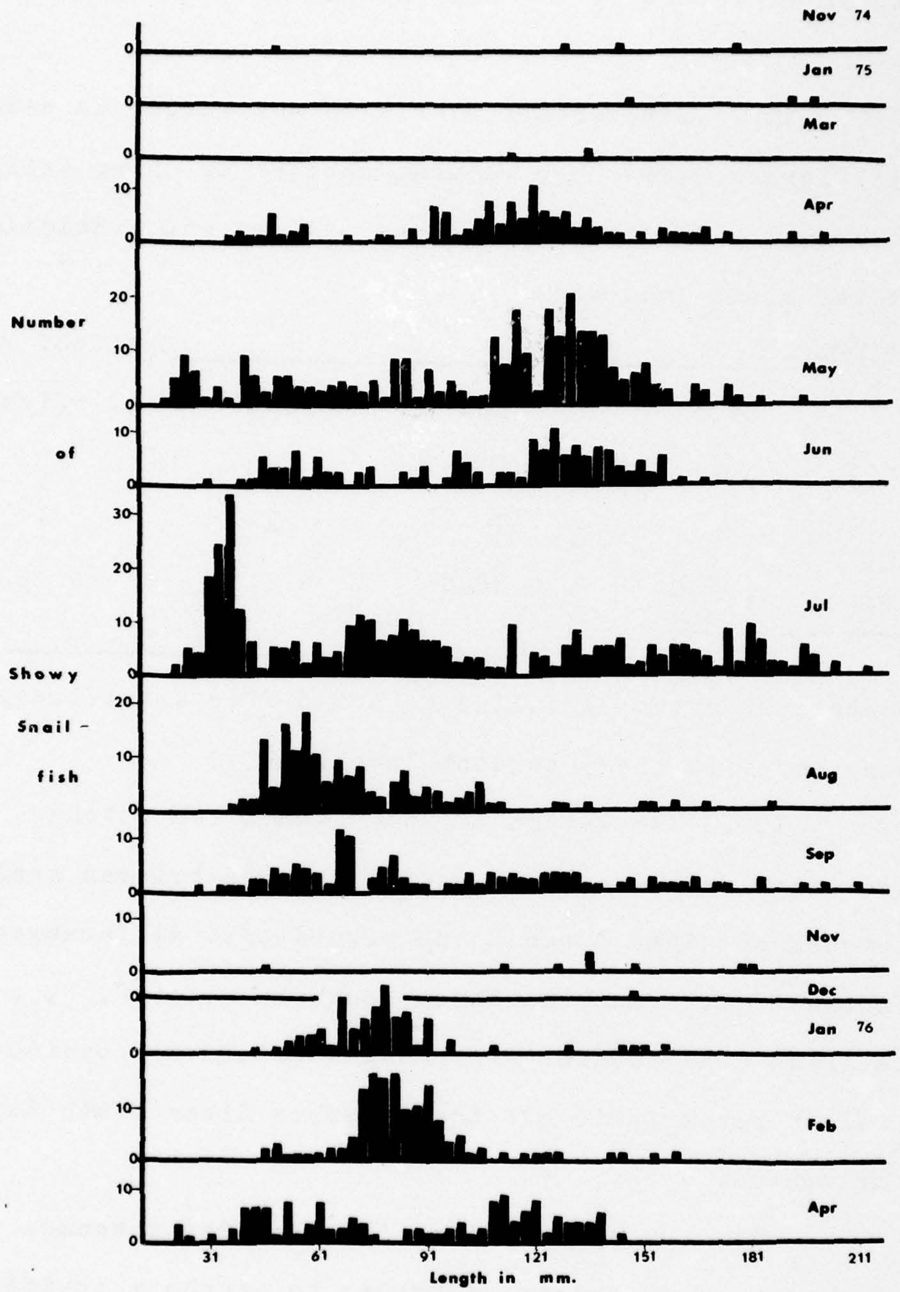

Figure E23. Monthly length-frequency histogram of showy snailfish (Liparis pulchellus) taken with an 8-m trawl net between October 1974 and April 1976.

to month as reflected by the nonsignificance of the interaction.

109. Determination of a Q-test factor to assess the significance difference between catches of showy snailfish at the site resulted in a value of z=1.668. Relationship of the sites follows:

LARGEST MEAN ______________________________ SMALLEST MEAN

Site	Site	Site	Site	Site
B	A	C	D	E
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
3.5900	3.0500	0.8800	0.5100	0.3500

Those means above the same line do not differ significantly from each other at the 5 percent level.

110. The Q-test of showy snailfish catches revealed there was essentially no difference between snailfish catches at sites A and B but significant differences between these sites and the three southern sites C, D, and E. Snailfish distribution differences should be considered a spatial characteristic off the Columbia River mouth during the four months.

111. Showy snailfish (Figure E24) consumed a wide variety of organisms. Similar to staghorn sculpins, the snailfish have stomachs that can expand to accommodate larger food items. Numerically, cumaceans, D. dawsoni, and amphipods, A. tridens, dominated the prey items.

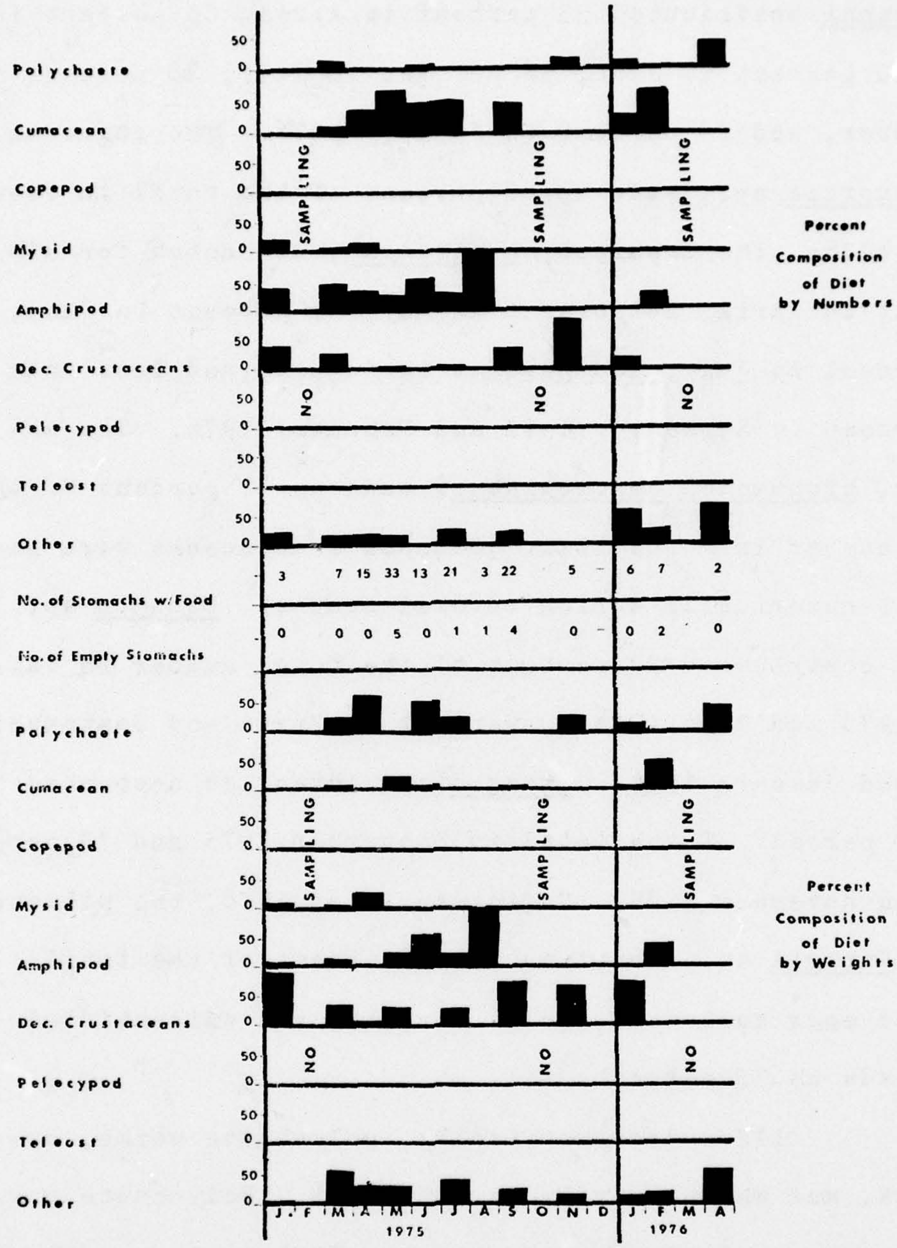

Figure E24. Monthly comparisons of showy snail-fish expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

D. dawsoni contributed 33 percent in April, 66 percent in May, 50 percent in June, 52 percent in July, 48 percent in September, and 29 percent in January 1976. The cumacean, *Mesolamprops* sp., made up 63 percent of the total in February 1976. The amphipod, *A. tridens*, accounted for 33 percent in April, 24 percent in May, 45 percent in June, 29 percent in July, 100 percent in August, and less than 25 percent in September 1975 and February 1976. The amphipod, *Hippomedon denticulatus*, made up 42 percent of the total number in March 1976. Decapod crustaceans were important numerically during several months. *Crangon* sp. adults contributed 33 percent of the total number in January 1975 and less than 20 percent in March and September 1975 and January 1976. *Crangon* sp. juveniles accounted for 29 percent of the total in September 1975 and 70 percent in November 1975. During April of 1976, the polychaete worm, *Nothria* sp., contributed 33 percent of the total; liparid eggs accounted for 34 percent; and unidentified eggs made up 33 percent.

112. Gravimetrically, polychaete worms, amphipods, and shrimp were most important. Polychaete worms were important food items during the 1975 spring months. In April, *Nereidae* sp., *Nothria* sp., and *Nephtys* sp. were eaten. In June, unidentified Glyceridae made up 37 percent while in July, *Glycinde picta*, *Nothria* sp., and *Nephtys* sp. were consumed. In April of 1976, *Nothria* sp. accounted for

39 percent of the total weight. The amphipod, A. tridens, made up 24 percent of the total weight in May 1975, 42 percent in June, 100 percent in August 1975, and 34 percent in February 1976. Shrimp adults, Crangon sp., contributed 97 percent of the weight in January 1975, 33 percent in March, less than 25 percent in April, May, and July; 30 percent in September 1975; and 77 percent in January 1976. Crangon sp. juveniles accounted for 40 percent of the weight in September 1975 and 63 percent in November 1975. Liparid eggs contributed 47 percent of the total weight in March 1975, smaller percentages in May and July 1975, and 46 percent in April 1976.

113. Briefly, the showy snailfish consumed a variety of polychaete worms, especially Nothria sp.; the amphipod A. tridens was eaten during late winter, spring, and early summer. Adult Crangon sp. were consumed throughout the year while the juveniles were eaten in late summer and early fall. The snailfish consumed snailfish eggs sporadically throughout the study. Snailfish consumed a variety of organisms but most were not eaten in quantity. Additional food items consumed at least once were:

Polychaete:
- Glyceridae

Cumacean:
- Mesolamprops sp.
- Diastylopsis dawsoni
- Colurostylis occidentalis

Mysid:
- Neomysis kadiakensis
- Acanthomysis davisi
- Acanthomysis nephrophthalma
- Archaeomysis grebnitzkii

Amphipod:
- Unident. amphipod
- Ampelisca macrocephala
- Pleusymptes subglaber
- Photis californica

continued

Synchelidium sp.
Paraphoxus sp.
Monoculodes sp.
Decapod crustaceans:
Anomuran
Decapod zoea
Cancer sp. megalops
Cancer sp. juv.
Pelecypod:
Pelecypod juv.

Teleost:
Microstomus pacificus juv.
Rockfish larvae
Other:
Olivella sp. (gastropod)
Liparid eggs
Unident. fish eggs
Tecticeps sp. (isopod)
Synidotea angulata (isopod)
Unident. animal material
Unident. vegetation

114. During July 1975, showy snailfish stomachs were sampled before disposal at the experimental site. Four stomachs contained food items and one was empty. A polychaete worm, Nothria sp., made up 25 percent of the total number and 19 percent of the weight. Shrimp, Crangon sp., were the most important food item and accounted for 50 percent of the number and 49 percent of the weight. The snailfish consumed snailfish eggs, which accounted for 26 percent of the total weight.

Pacific sanddab (Citharichthys sordidus)

115. Pacific sanddab is a left-eye flatfish usually found in shallow water but taken in depths to 600 m. It is recognized by its light brown color, uniform scale pattern, and large eye which is longer than the snout. It is found between Baja California and the Bering Sea and is reported to reach a length of 41 cm. It is harvested commercially in California and considered a desired food fish.

116. This sanddab was one of two Bothidae

captured at the study sites. A total of 1680 Pacific sanddab were captured, representing 1.9 percent of all finfish. They appeared in 68.9 percent of all trawl tows. Some Pacific sanddab were taken throughout the year but the majority were captured between June and September, indicating the seasonality of the species.

117. The Pacific sanddab ranged in length from 34 to 349 mm. A monthly length-frequency histogram for the species is presented in Figure E25. Size group separation is apparent with a young size group entering the trawl catch in spring. Adult fish appeared throughout the year but the larger size groups overlapped and their separation by lengths was not possible. The length-frequency of Pacific sanddab caught at the experimental test site was compared with the combined length-frequency of those found at other sites using the Kolmogorov-Smirnov two-sample test (Figure E26). The tests were made for July and August 1975, but low numbers of fish nullified further tests for September 1975 and April 1976. The tests revealed sanddab at experimental test site E during July were similar in length to those taken primarily at the two nearest other sites. In August the situation changed completely. Sanddab at the test site were predominantly small (<15 cm), while those captured primarily at sites C and D usually were large (>20 cm). The Kolmogorov-Smirnov test for August indicated significant differences existed between

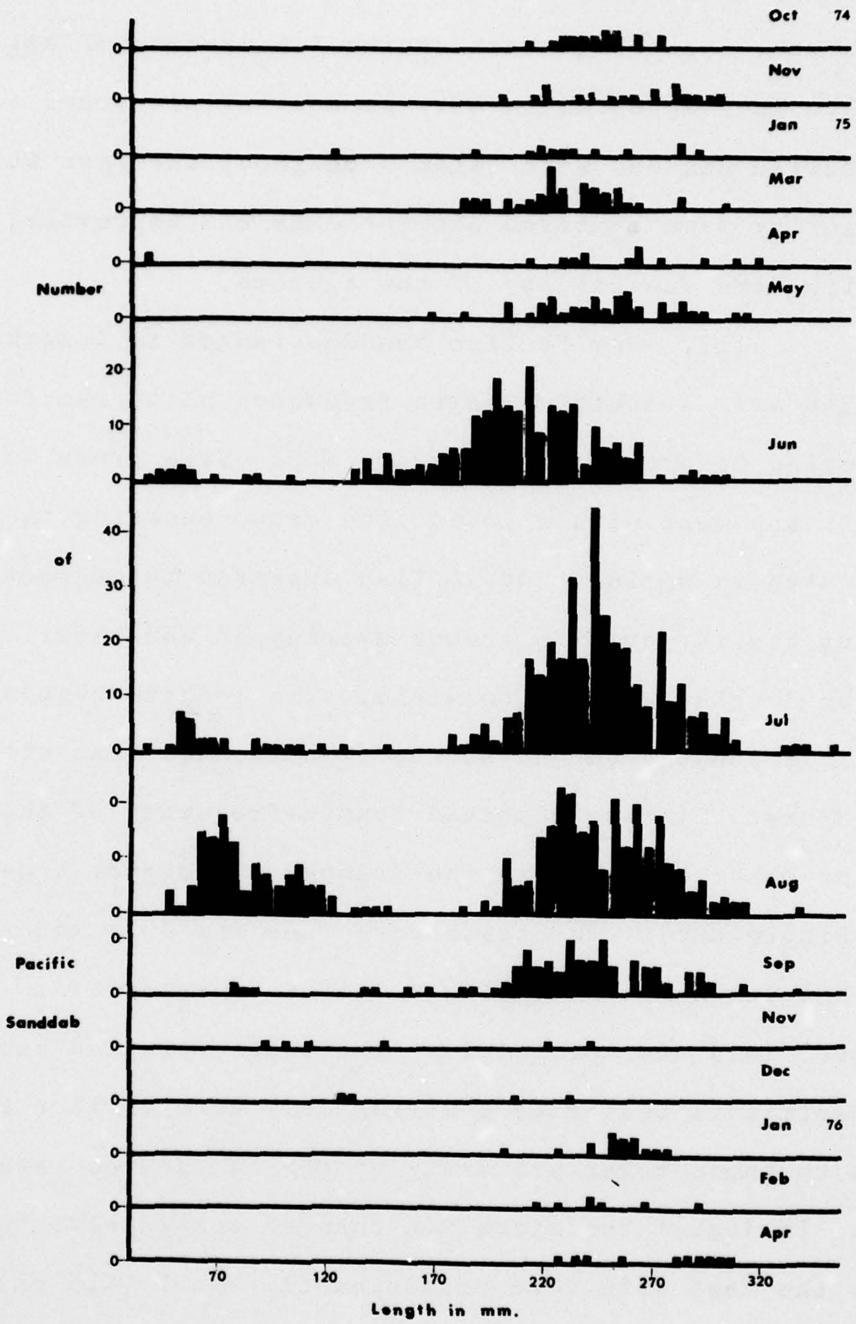

Figure E25. Monthly length-frequency histogram of Pacific sanddab (Citharichthys sordidus) between October 1974 and April 1976.

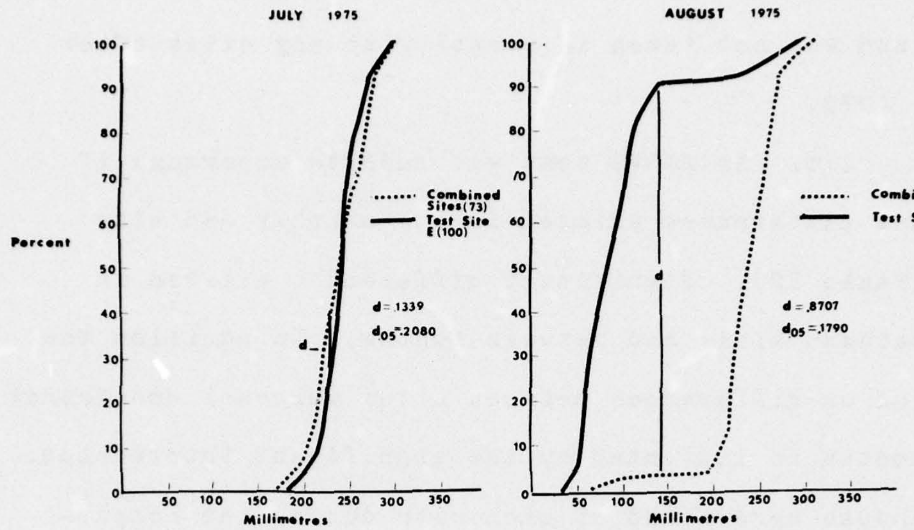

Figure E26. A two-month comparison of the cumulative percent of Pacific sanddab (<u>Citharichthys sordidus</u>) lengths captured with trawl gear.

Pacific sanddab lengths at the sites. Pacific sanddab is seasonal and was not taken in quantity at any sites after September 1975.

118. An ANOVA test was made to determine if significant differences existed in the monthly and site catches (Table E2). Significant differences existed in catches between sites and between months. In addition the interaction or differences between sites were not consistent between months as indicated by the significant interaction. Though sanddab were found at each site during the comparative sampling period, they were common only at the southern sites during July and August 1975.

119. Determination of the Q-test factor for testing the relationship between sanddab catches at the sites resulted in a value of z=0.8258. The alignment of sites follows:

LARGEST MEAN ______________________ SMALLEST MEAN

Site C	Site D	Site E	Site A	Site B
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
2.7650	2.5488	2.1788	1.3963	1.3850

Those means above the same line do not differ significantly from each other at the 5 percent level.

120. A comparison of the mean catch at each

site with a Q-test revealed the southern sites C and D, where the Pacific sanddab were common, were significantly different from sites A and B where species numbers were substantially lower. Catches at experimental test site E fall between northern and southern sites and were not significantly different from the other four sites.

121. Pacific sanddab (Figure E27) consumed amphipods and anchovies, supplemented with crangonid shrimp. Numerically, the amphipod, *A. tridens*, was important in the spring and summer months, with the exception of April. They contributed the following proportion of the total number of organisms: 60 percent in May 1975; 68 percent in June; 53 percent in July; 62 percent in August; and 59 percent in September 1975. During spring and winter, anchovies, *E. mordax*, were consumed in quantity. They accounted for 60 percent of the total number in January 1975, 86 percent in March, 93 percent in April, smaller percentages in May and December, and 100 percent in January and April of 1976. In November 1975, shrimp juveniles, *Crangon* sp., made up 67 percent of the total number while in February of 1976 *Crangon* sp. adults contributed 67 percent of the total.

122. Gravimetrically, anchovies dominated the food items during the study period. The amphipod, *A. tridens*, was less important when analyzed by weights but did provide food during the summer when the anchovies were less abundant.

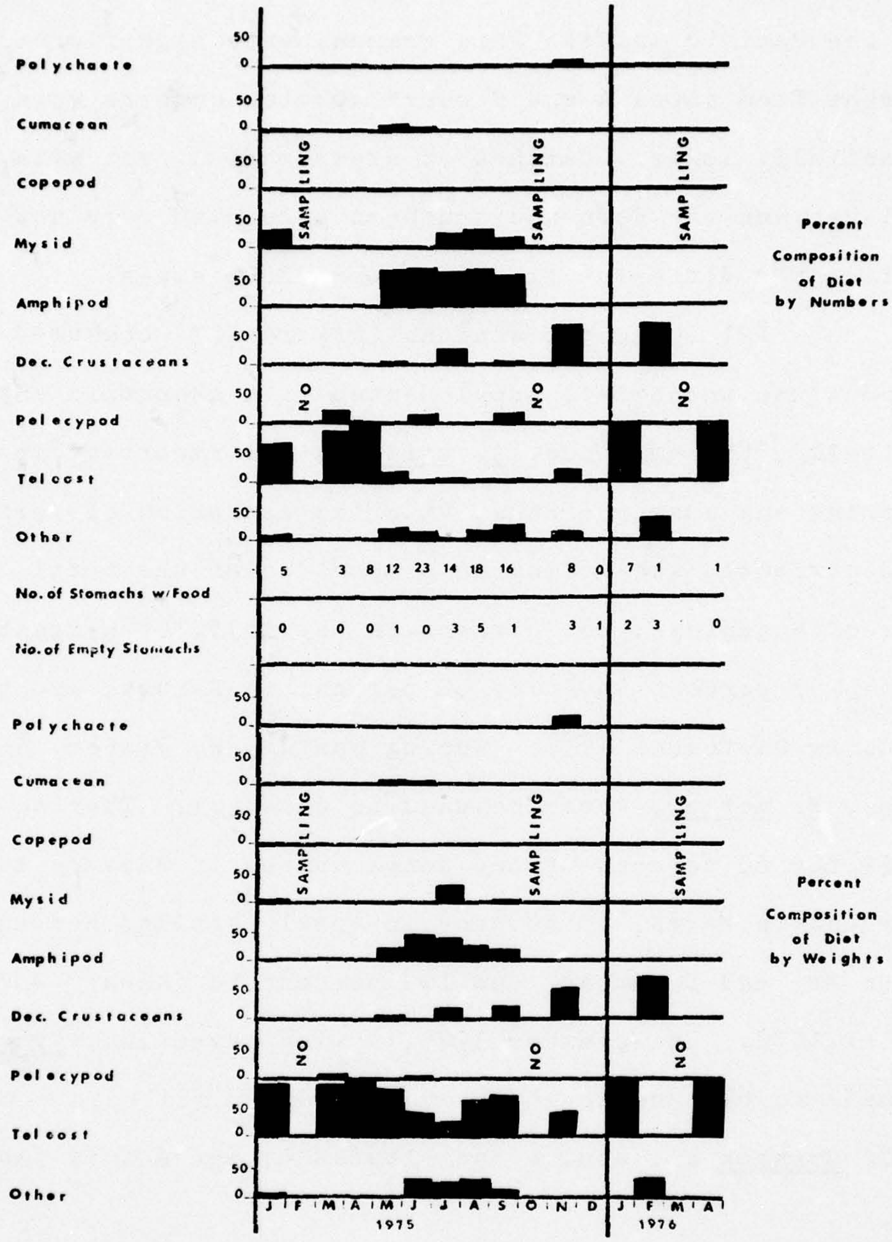

Figure E27. Monthly comparisons of Pacific sand-dab expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

A. tridens made up less than 40 percent in May, June, July, August, and September 1975. Anchovies, E. mordax, made up 91 percent of the total weight in January 1975, 99 percent in March, 99 percent in April, 72 percent in May, 37 percent in June, smaller amounts in July and August, 66 percent in September, 24 percent in November 1975, and 100 percent in January and April of 1976. Crangonid shrimp were a major prey item during two months. In November of 1975, Crangon sp. juveniles made up 49 percent of the total, and Crangon sp. adults accounted for 71 percent of the total in February of 1976.

123. In summary, Pacific sanddab fed heavily on anchovies, E. mordax, during the fall and winter months and to a lesser degree during the spring and summer months. The amphipod, A. tridens, and shrimp, Crangon sp., were the other major food items and seemed to be utilized when anchovy were less abundant. The Pacific sanddab has a large mouth and, though not a large flatfish, apparently is primarily pisciverous. Other food items consumed at least once were:

Polychaete:
  Glyceridae
Cumacean:
  Colurostylis occidentalis
  Diastylopsis dawsoni
Copepod:
  Calanus sp.
Mysid:
  Neomysis kadiakensis
  Acanthomysis davisi
  Acanthomysis nephrophthalma

Amphipod:
  Hippomedon denticulatus
  Ampelisca sp.
  Synchelidium sp.
  Pleusymptes subglaber
Decapod Crustaceans:
  Cancer magister megalops
  Cancer magister juv.
Pelecypod:
  Siliqua patula juv.
  Siliqua patula necks

Teleost:
- Unident. fish
- *Allosmerus elongatus*
- *Isopsetta isolepis* juv.
- Osmerid larvae

Other:
- *Synidotea angulata* (isopod)
- *Tecticeps* sp. (isopod)
- *Olivella* sp. (gastropod)
- Unident. organic material
- Unident. mineral material

124. Pacific sanddab were sampled at the test site twice in July and once each in August and November of 1975 (Figure E28). Predisposal sampling showed a diet, by numbers, of 75 percent mysids, *N. kadiakensis*, and 25 percent amphipods, *A. tridens*. During disposal in July, fewer mysids (25 percent) and more amphipods (50 percent) were eaten in addition to an anchovy, *E. mordax*. In August, *N. kadiakensis* contributed 58 percent of the numbers and *A. tridens* 28 percent. In November (postdisposal), juvenile shrimp, *Crangon* sp., made up 80 percent of the total diet.

125. By weights, mysids and amphipods were important for the predisposal period in July 1975, making up 75 and 25 percent of the total, respectively. However, during the disposal sampling in July, the anchovy made up 90 percent of the total weight. The graph of weights for August and November was dissimilar to the numerical graph with *N. kadiakensis* accounting for 29 percent but juvenile razor clams, *S. patula*, making up 19 percent and juvenile fish 38 percent. The fish were juvenile butter sole, *I. isolepis*, and smelt larvae. In November, *Crangon* sp.

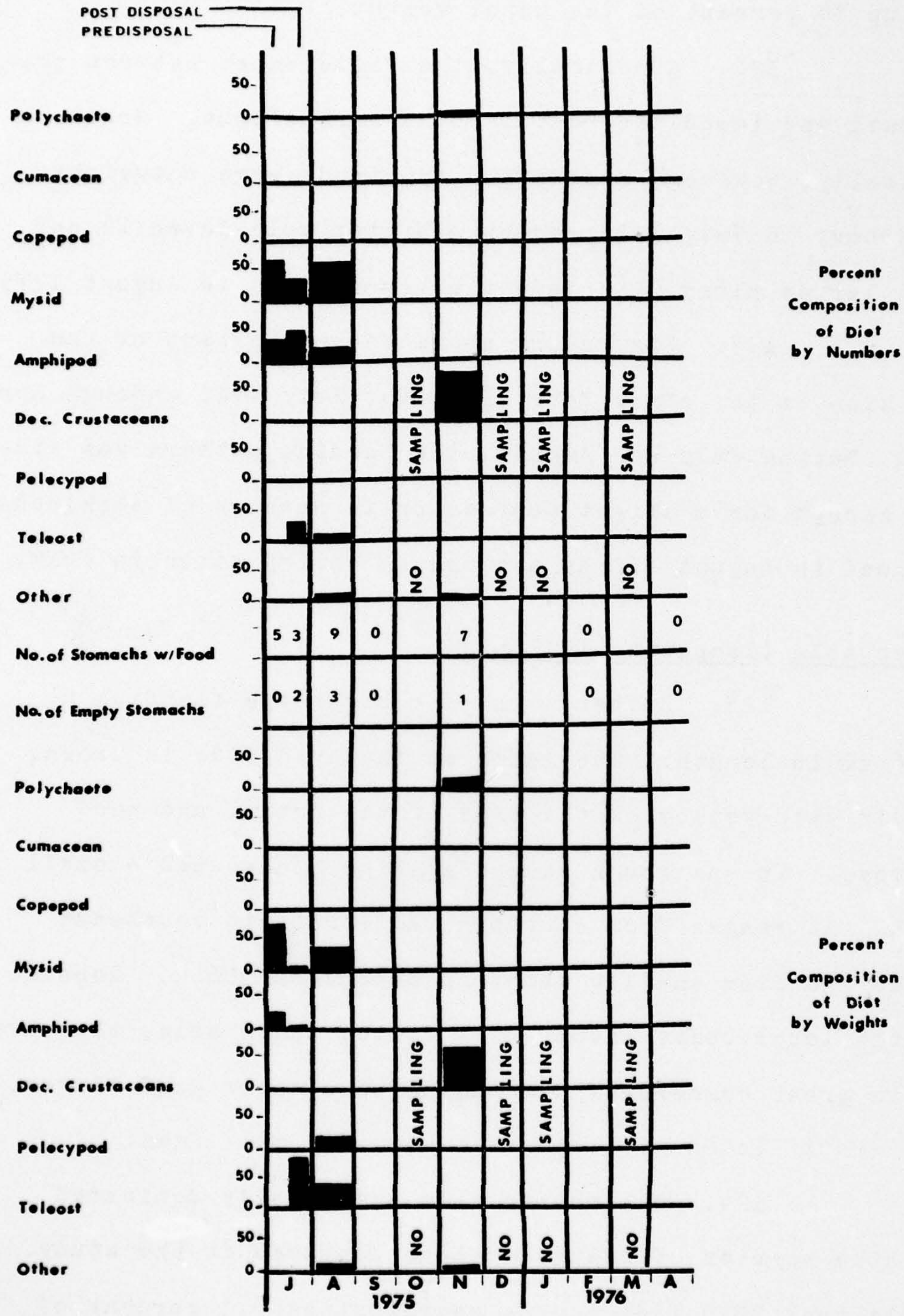

Figure E28. Monthly comparisons of Pacific sanddab from the test site expressed as percent composition of diet by numbers and weights, July 1975 through April 1976.

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AQUATIC DISPOSAL FIELD INVESTIGATIONS, COLUMBIA RIVER DISPOSAL --ETC(U)

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made up 78 percent of the total weight.

126. Numerically, the diffe
disposal and immediate postdisposal were
metrically, however, mysids and amphipod
by anchovy in July 1975 and by a butter
smelt larvae along with juvenile razor c

127. Figure E29 shows the c
test site to the other four sites for Ju
1976. During July and August, the feedi
ilar except for a slight depression in n
consumed in August and an absence of shr

Butter sole (Isopsetta isolepis)

128. Butter sole is a right
to 46 cm in length. The color on the ey
usually with yellow on the tips of the d
fin rays. It has rough sandpaper-like s
mouth. It ranges from southern Californ
Alaska and from shallow water to depths
of high labor costs involved to fillet t
not in great commercial demand, despite
Some are filleted with the rest used for

129. The butter sole numeri
the nine species of Pleuronectidae captu
Trawls took 7020 individuals representin
all finfish captured. Butter sole appea

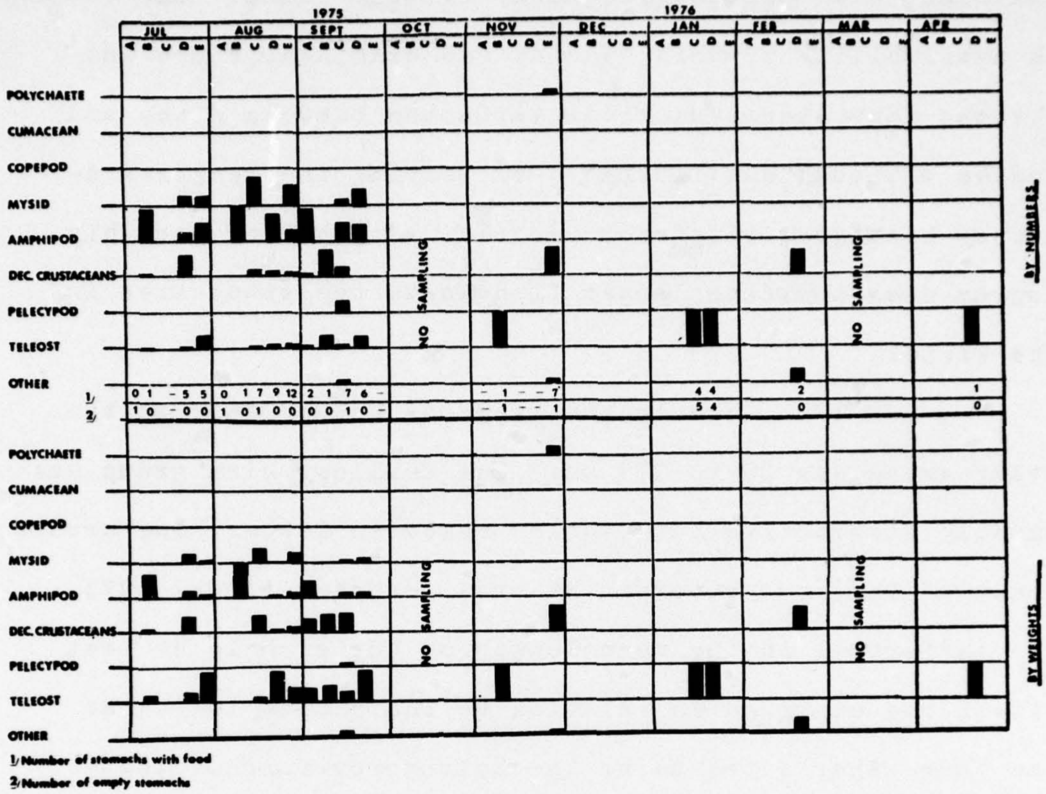

Figure E29. Comparisons of five sampling sites by month for Pacific sanddab expressed as percent composition of diet by numbers and weights, July 1975 through April 1976.

151 tows, a 96 percent frequency of occurrence. The seasonal availability of this species was examined; there was obvious short-term numerical variation between sites and months although not indicated by viewing the length-frequency histogram (Figure E30). The length-frequency histogram does indicate larger fish leave the study area in the winter.

130. The length range of butter sole at the study areas was 30 to 375 mm. The smallest size group was usually distinctive but overlap obscured larger size groups. Young-of-the-year entered the trawl catches in May 1975. The difference in the mean length of butter sole at test site E was examined in relation to their mean length at the four other sites using the Kolmogorov-Smirnov test (Figure E31). The butter sole was the single finfish species captured in sufficient numbers to follow it through four months of comparative testing. The initial month of July 1975 indicated the differences between cumulative lengths were significant at the 10 percent level but not at the 5 percent level. Also, greater numbers of intermediate size butter sole were taken at test site E. In August and September 1975, the length differences were significant at the 5 percent level. During these months small butter sole were captured at experimental test site E. In April 1975, seven months after dredged material disposal ceased, butter sole lengths continued to differ

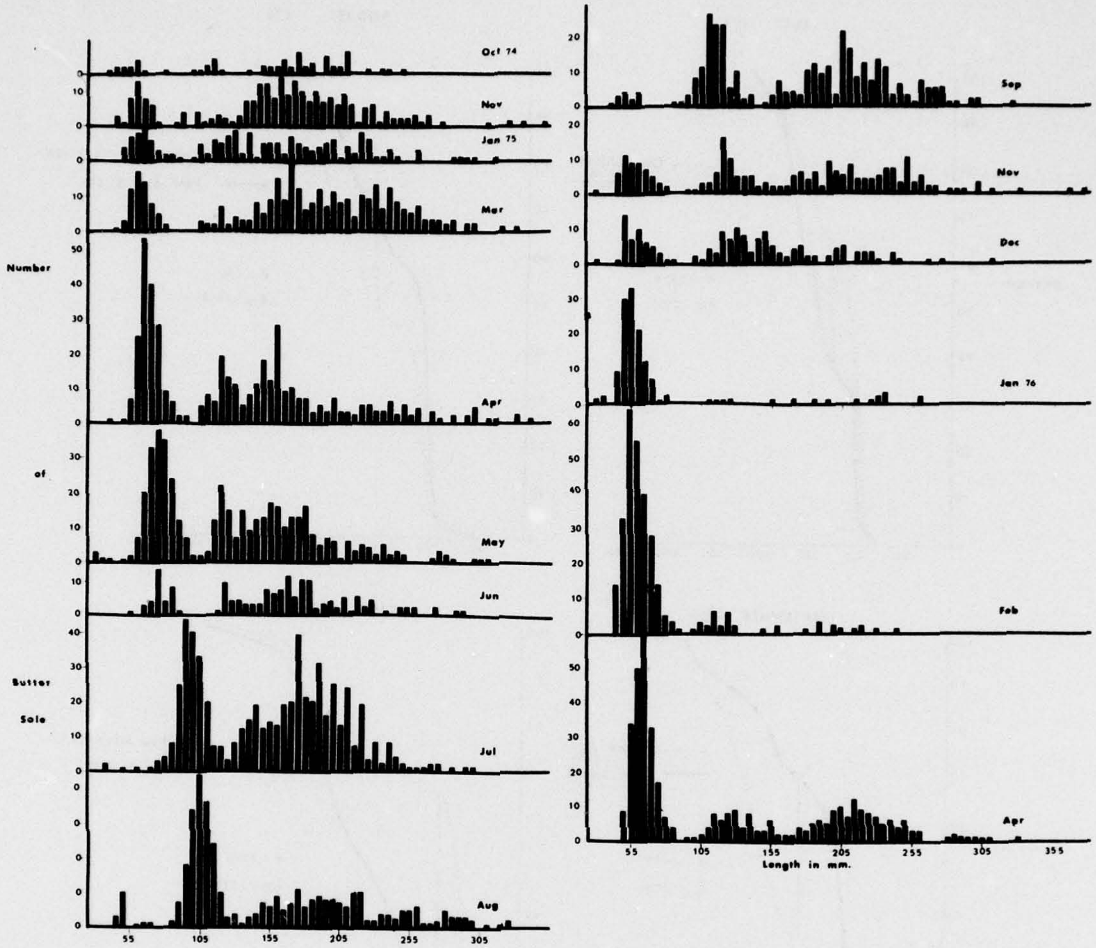

Figure E30. Monthly length-frequency histogram of butter sole (Isopsetta isolepis) captured with 8-m trawl net between October 1974 and April 1976.

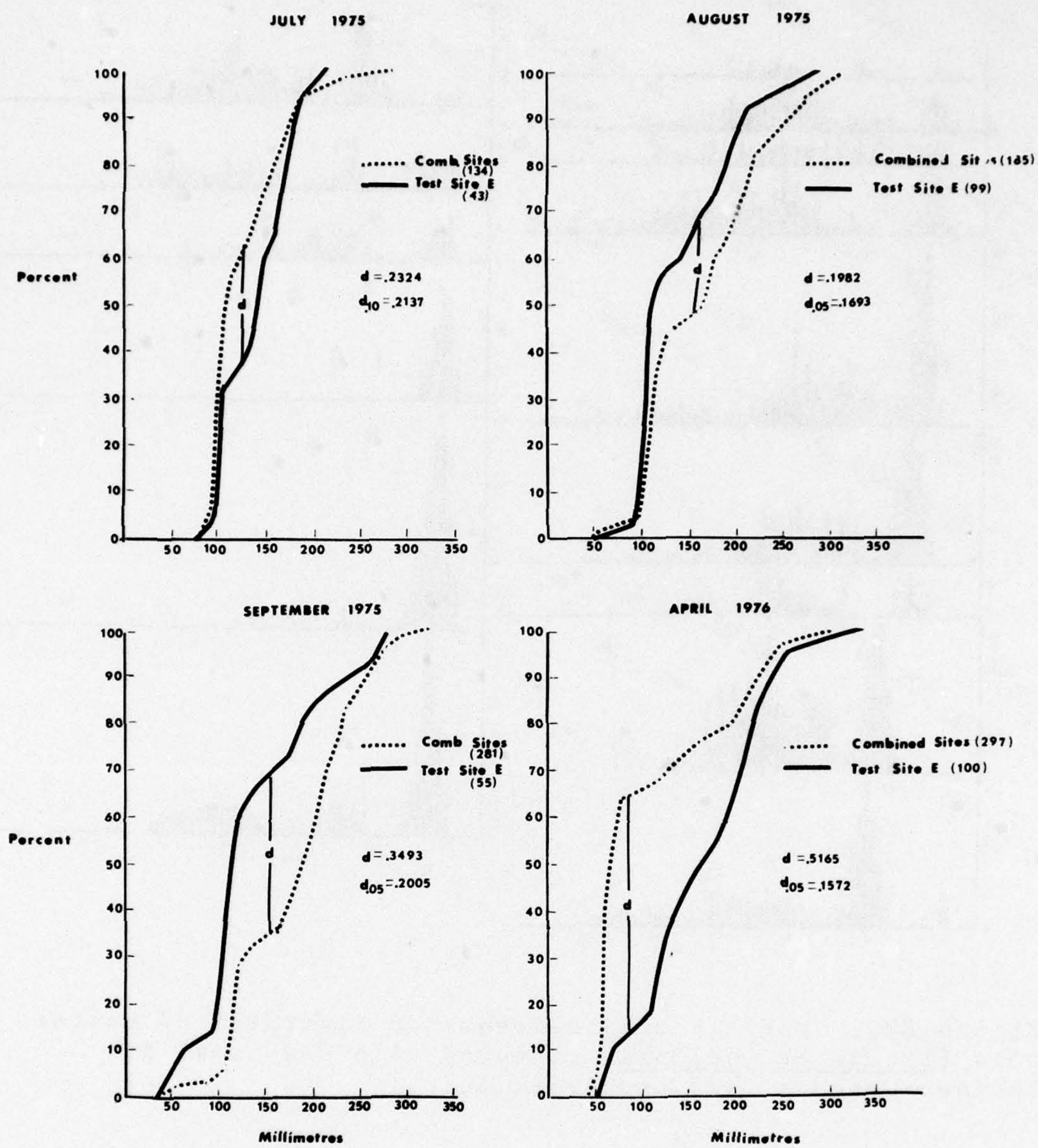

Figure E31. A four-month comparison of the cumulative percent of butter sole (*Isopsetta isolepis*) lengths taken with trawl gear.

at the 5 percent level; however, larger rather than small butter sole occupied the test site.

131. An ANOVA test for butter sole catches between sites and months was prepared (Table E2). It was determined that significant differences existed at the 5 percent level among sites and also among months. Moreover these differences were not consistent from month to month as indicated by the significant interaction. A consistently high numerical incidence of butter sole at the southern sites overshadowed the smaller numbers taken at northern sites A and B. Differences in trawl catches were particularly noticeable from July to September 1975 and less evident in April 1976.

132. In order to test the numerical relations of butter sole between sites, a Q-value of $z=0.7477$ was calculated. The significance of catches among sites follows:

LARGEST MEAN ______________________________ SMALLEST MEAN

Site	Site	Site	Site	Site
C	E	D	A	B
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
4.6063	3.7875	3.4950	2.1225	2.0263

Those means above the same line do not differ significantly from each other at the 5 percent level.

133. The test comparing the site mean catches

indicated a three-area distribution of the species. The centrally situated site C had the highest consistent catches, and these were significantly different from catches at the other four sites. Southern sites D and E catches differed significantly from northern sites A and B.

134. Butter sole consumed a variety of organisms (Figure E32). Numerically, cumaceans were important from late winter through summer. Amphipods were eaten consistently throughout 1975 but were numerically most important in January and November. Shrimp and young crabs were also important diet components in the winter. Juvenile razor clams and their siphons were important food in the spring and summer months. As with other species, an important food item for butter sole was the cumacean, D. dawsoni. This species accounted for 52 percent of the total number in March 1975, 94 percent in April, 82 percent in May, 65 percent in June, 50 percent in July, 30 percent in August, and smaller amounts in September and December 1975. The cumacean, Mesolamprops sp., made up 70 percent of the total in April 1976. The amphipod, A. tridens, contributed 73 percent of the total in January 1975, less than 15 percent from March through September, and 48 percent in November 1975. Adult shrimp, Crangon sp., made up 53 percent of the total in December 1975, 17 percent in January 1976, and 50 percent in February 1976. Juvenile razor clams, Siliqua patula, contributed less than 35 percent

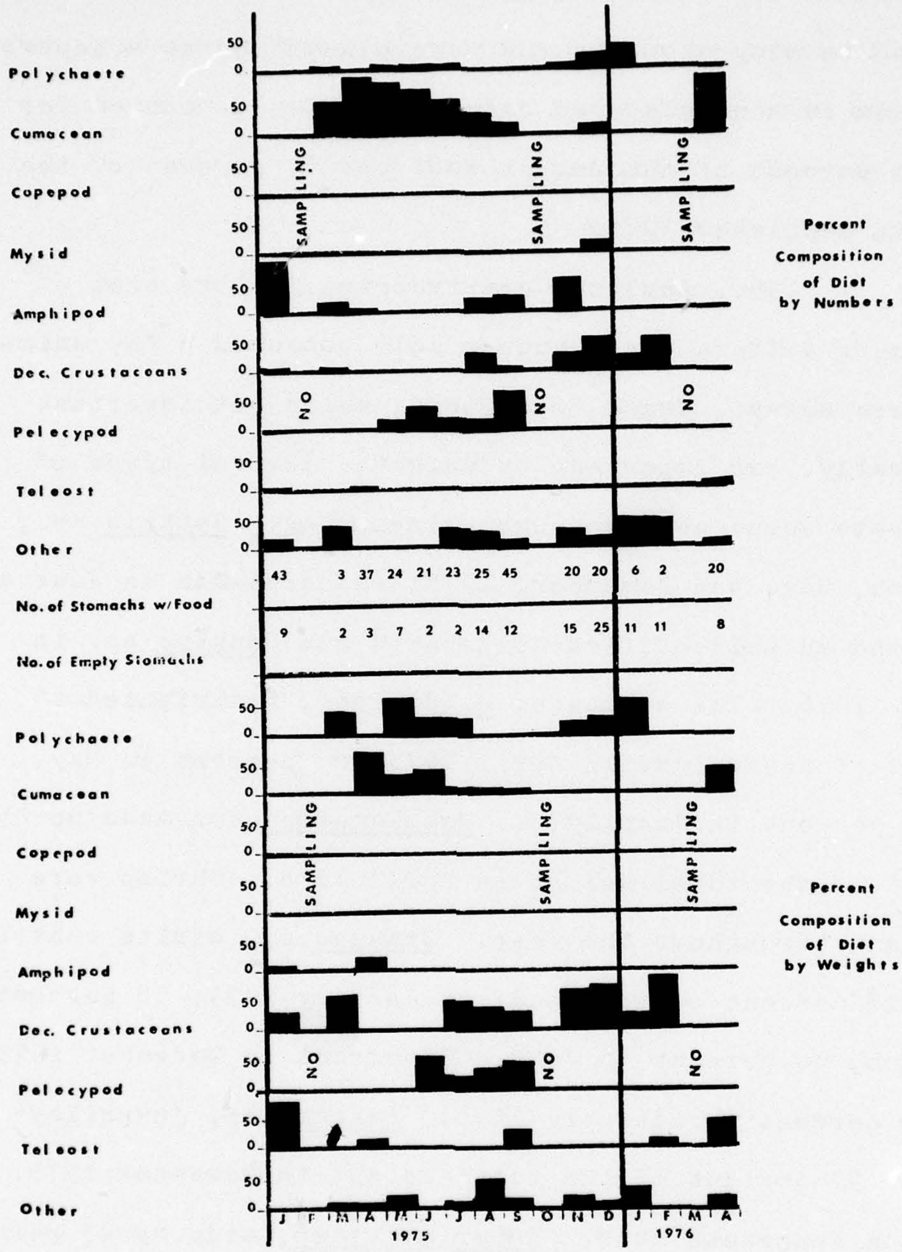

Figure E32. Monthly comparisons of butter sole expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

of the total from May through September 1975. Necks appeared in many stomachs and were classified as a separate food item in the pelecypod category. They accounted for a small percent of the August food but 67 percent of the total in September 1975.

135. Analyzed gravimetrically, the plot of prey importance differs since butter sole consumed a few animals that were heavy. These food items, while not important numerically, are important by weight. Several types of polychaete worms were consumed, including: *Nothria* sp., in March, May, and November, 1975; Ampharetidae in June and July; and an unidentified polychaete and *Nephtys* sp. in January 1976. The cumacean, *D. dawsoni*, contributed 66 percent of the weight in April 1975, 25 percent in May, and 34 percent in June 1975. *Mesolamprops* sp. made up 25 percent of the total weight in April 1976. Shrimp were important throughout the year. *Crangon* sp. adults contributed 18 percent of the total in January 1975, 58 percent in March, 36 percent in July, 65 percent in December 1975, and 94 percent in February 1976. *Crangon* sp. juveniles made up 59 percent of the total weight in November 1975. Juvenile Dungeness crab, *Cancer magister*, made up 25 percent or less of the total in July, August, and September 1975. Juvenile razor clams, *S. patula*, were important gravimetrically during four months and accounted for 49 percent of the total in June 1975 and less than 25 percent in July,

August, and September. Clam siphons made up 13 percent of the total weight in September. In January 1975, the northern anchovy, _E_. _mordax_, made up 72 percent of the total, 28 percent in September 1975, and 50 percent in April 1976.

136. The summary of food habits for butter sole revealed differing number and weight patterns for prey items. _D_. _dawsoni_ were important by weight and numbers during spring and summer; however, in April of 1976 _Mesolamprops_ sp. dominated the diet and few _D_. _dawsoni_ were counted. Polychaete worms were eaten throughout the year, but in low numbers. The polychaetes consumed were quite large: up to several centimetres in length. Amphipods, _A_. _tridens_, though evident in the diet during all of 1975, were not important by weight. The overwhelming numbers of cumaceans diminished the importance of other food items, such as amphipods and polychaetes. Adult and juvenile crangonid shrimp were consumed all year but not heavily during late fall 1975 and early winter 1976. Juvenile razor clams, _S_. _patula_, and clam siphons were important late spring through summer of 1975. Anchovies were consumed heavily in January and September 1975 and April 1976. Figure E33 shows these seasonal trends. Additional food items consumed at least once were:

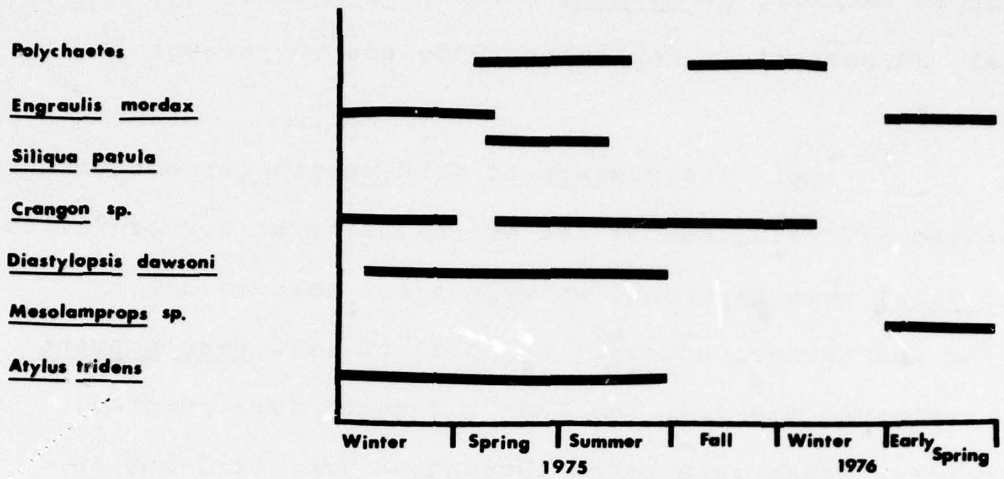

Figure E33. Seasonal variations in main diet of butter sole.

Polychaete:
- Unident. polychaete
- Syllidae
- *Spiophanes* sp.
- Nereidae
- *Eteone* sp.
- Ampharetidae
- Goniadidae

Cumacean:
- *Lamprops* sp.
- *Colurostylis occidentalis*
- *Hemilamprops* sp.

Mysid:
- Unident. mysids
- *Neomysis rayii*
- *Neomysis kadiakensis*
- *Acanthomysis davisi*

Amphipod:
- *Photis californica*
- *Photis* sp.
- *Monoculodes* sp.
- *Hippomedon denticulatus*
- *Synchelidium shoemakeri*
- *Ampelisca* sp.
- Aoridae
- *Dulichia* sp.
- *Paraphoxus obtusidens*

Decapod Crustaceans:
- *Crangon franciscorum*
- *Cancer magister*
- *Cancer* sp. megalops
- *Cancer* sp. zoea
- *Pagurus* sp.

Teleost:
- Unidentified teleost
- *Isopsetta isolepis* juv.

Other:
- *Dendraster* sp. (starfish)
- Gastropod feet & opercula
- *Olivella* sp. (gastropod)
- *Synidotea angulata*- (isopod)
- *Tecticeps* sp. (isopod)
- Unident. mineral material
- Ophiuroid
- Unident. organic material

137. Little change was observed in the diet of butter sole at the test site between predisposal and disposal samples in July 1975 (Figure E34). However, changes began to occur in August with a depression in consumption of shrimp and an increase in *Tecticeps* sp. (isopod) and juvenile razor clam consumption. In September, some shrimp were eaten, but utilization of anchovies increased. Polychaetes were eaten in November, shrimp in February, and copepods and anchovies in April. For butter sole, shrimp consumption was slightly depressed during disposal but recovered by February, while isopod consumption showed the opposite trend.

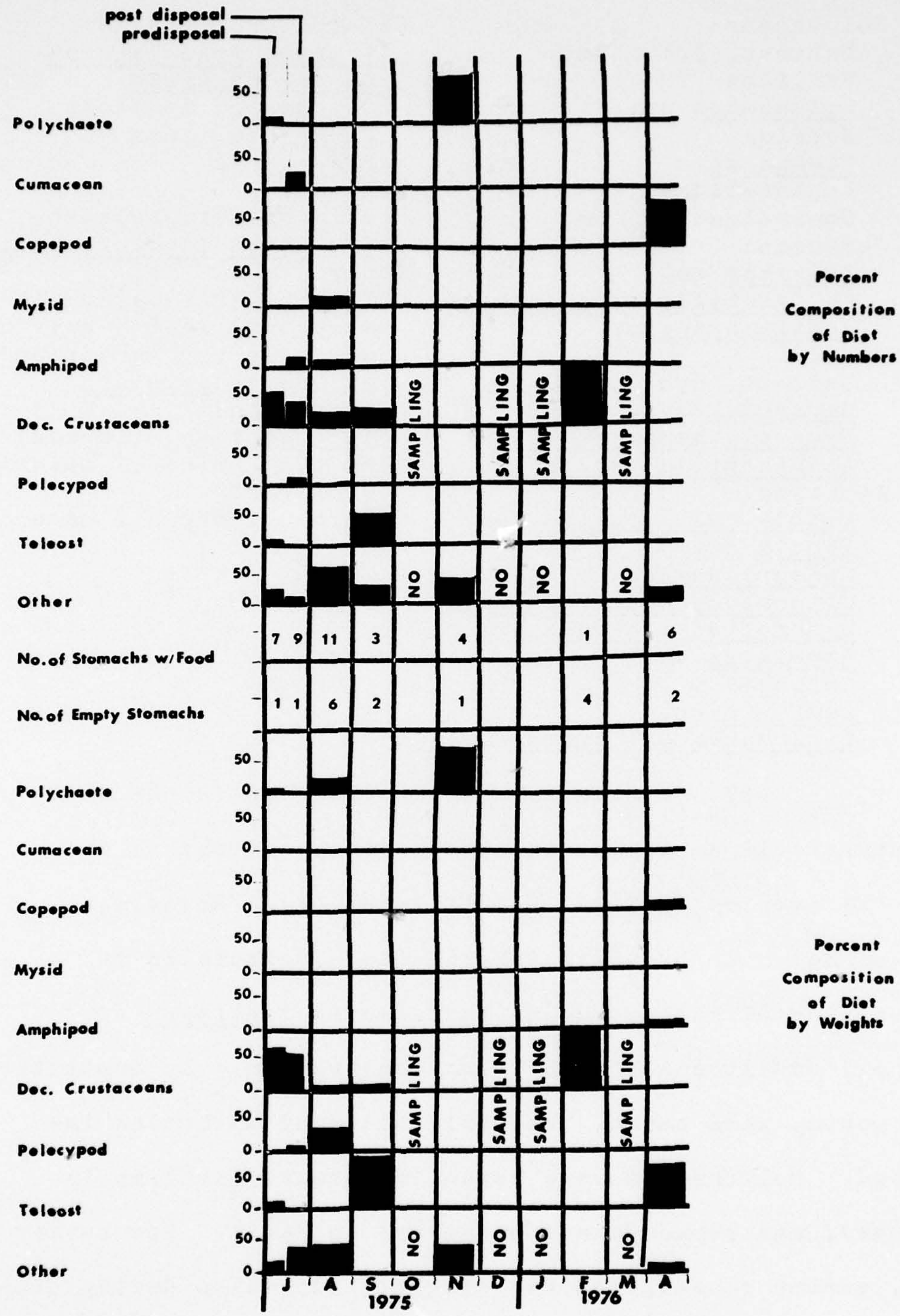

Figure E34. Monthly comparisons of butter sole from the test site expressed as percent composition of diet by numbers and weights, July 1975 through April 1976.

138. Figure E35 shows the comparison of the test site to the other four sites from July 1975 through April 1976. In July, butter sole from the test site showed an increased utilization of shrimp. In August the numbers of decapods eaten were reduced and polychaete consumption was unique to the test site. In September, decapod and teleost consumption increased but pelecypods were absent from test site stomachs yet present in stomachs from the other four sites. In April 1976, polychaete and cumaceans were not eaten at the test site, but copepod consumption was unique to the experimental area.

<u>English sole</u> (<u>Parophrys vetulus</u>)

139. English sole are a common flatfish species, symmetrical in shape with a pointed snout and uniformly brown on the eyed side. It is distributed in waters to 550 m from Baja California to the Gulf of Alaska. It is usually harvested in water less than 100 m in depth. Maximum length of a female English sole was 57 cm, that of a male 49 cm. The species frequently reaches 20 years of age, has a juvenile estuarine rearing stage, and migrates extensively. It is a highly valued commercial foodfish with ten million pounds harvested annually.

140. Trawl sampling took 5310 English sole, which represented 6.1 percent of all finfish. The English sole appeared in 138 tows (91.4 percent), ranking behind only

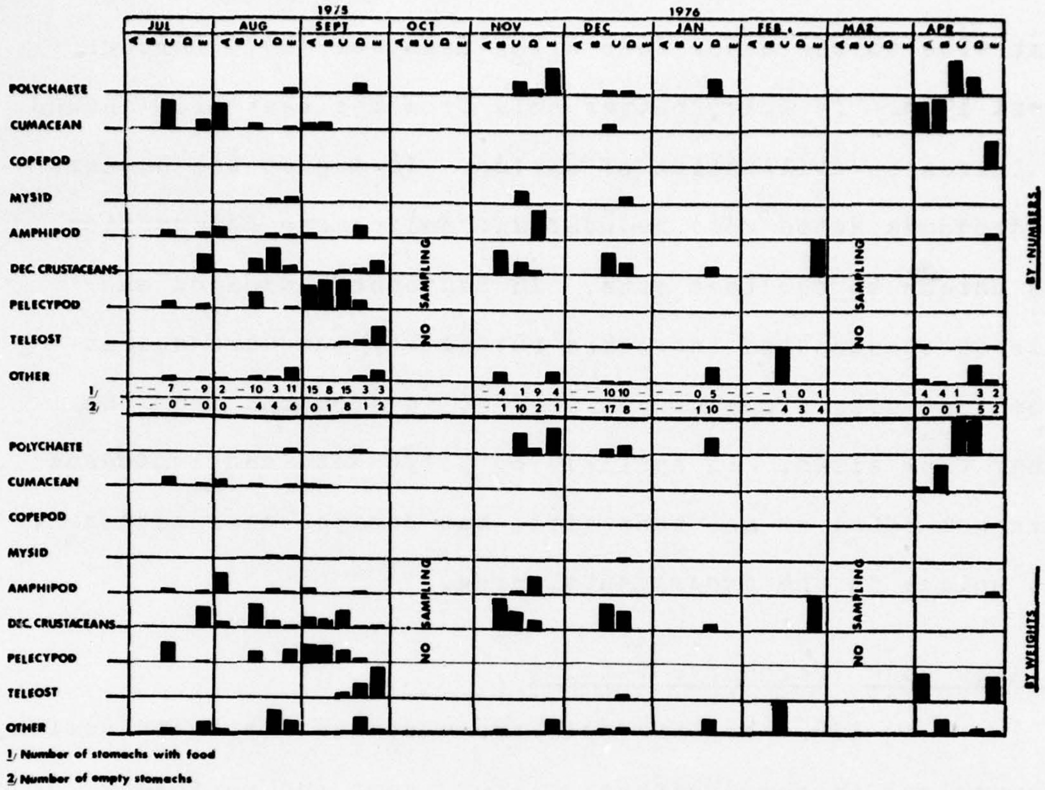

Figure E35. Comparisons of five sampling sites by month for butter sole expressed as percent composition of diet by numbers and weights, July 1975 through April 1976.

butter sole in frequency of occurrence. Catches of English sole were highest from May to November and lowest from December through April.

141. Sizes of English sole were apparently seasonally related at the study area since larger fish were captured during a period of greatest abundance while small individuals were captured during winter (Figure E36). The length-frequency histogram reveals few separate size groups and those that were apparent one month were usually indistinct the following month. An overall length range of 20 to 400 mm was observed. Young-of-the-year entered trawl catches in May 1975 but did not appear again until August. Lengths of English sole captured at the test site were consistently smaller than those captured at the other sites, particularly during July, August, and September 1975. Sufficient numbers for testing comparative lengths occurred only in July 1975 (Figure E37). During July 1975, English sole comparative lengths were significantly different than at other sites. Over 90 percent of the sole captured at test site E were under 250 mm while 50 percent at other sites were more than 250 mm.

142. An ANOVA for the catch of English sole between sites and between months is shown in Table E2. There was no significant difference in the catch of English sole between the five sampling sites. This was the only finfish species of 11 tested that failed to show a significant

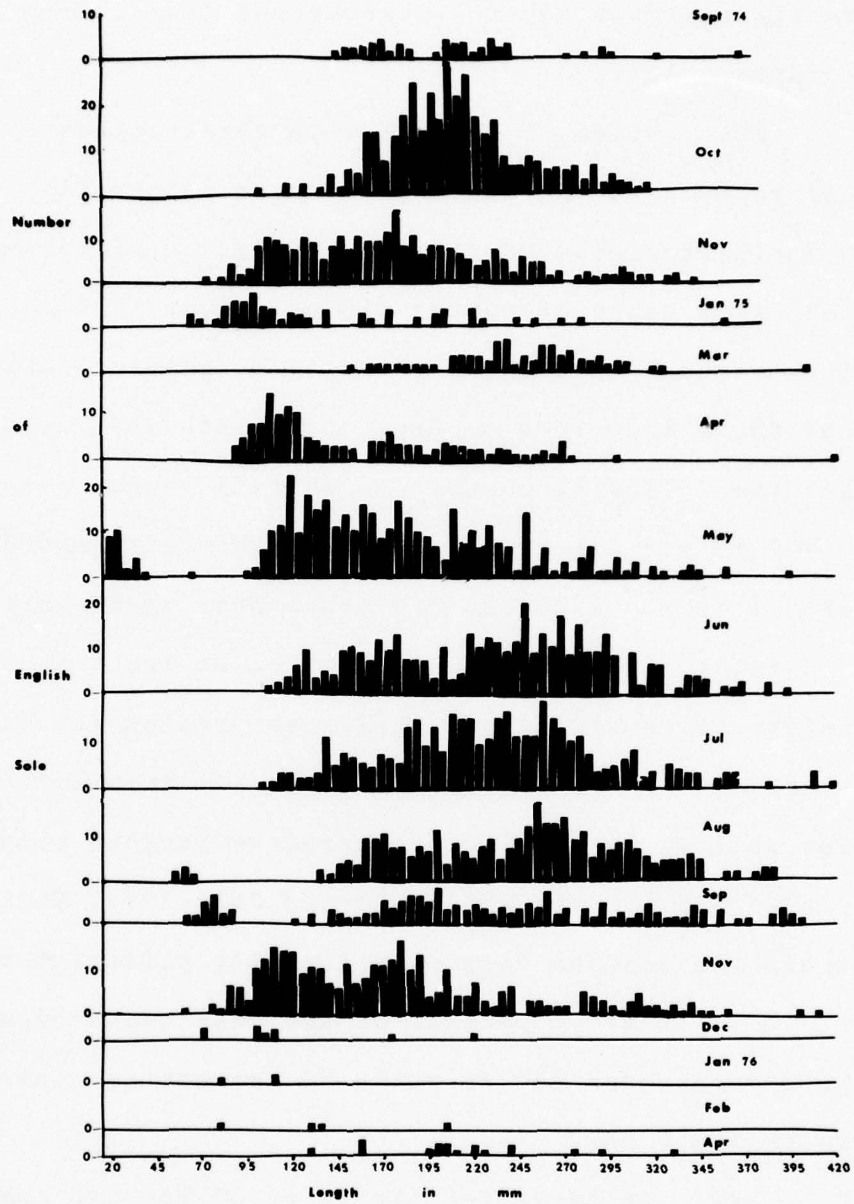

Figure E36. Monthly length-frequency histogram of English sole (Parophrys vetulus) captured with trawl gear.

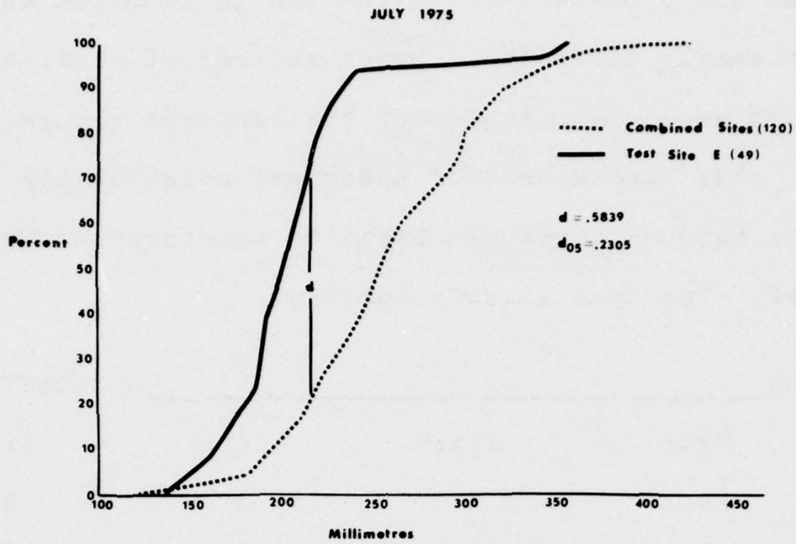

Figure E37. A comparison of the cumulative percent of English sole (Parophrys vetulus) lengths taken with trawl gear.

difference. The monthly trawl catches were significantly different at the 5 percent level and the interaction was also significantly different. Minor catches of English sole in April 1976 were responsible for the temporal change.

143. The Q-test of numerical relationship of English sole between sites was based on a determined value of z=0.9792. The relationship follows:

LARGEST MEAN ______________________________ SMALLEST MEAN

Site C	Site B	Site E	Site A	Site D
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
2.4787	2.3987	2.3950	1.9787	1.6812

Those means above the same line do not differ significantly from each other at the 5 percent level.

144. The Q-test of mean numerical catches of English sole at the five sites revealed no significant difference in catches between any of the sites. English sole were the single species with no significant difference in catch between sites.

145. English sole (Figure E38) consumed a limited diet, more so than other flatfish species. Numerically, the cumacean, D. dawsoni, was the primary food item through 1975. Those English sole used for analysis in 1975 had empty stomachs. D. dawsoni made up 79 percent in March 1975, 96 percent in April, 94 percent in May, 74 percent in

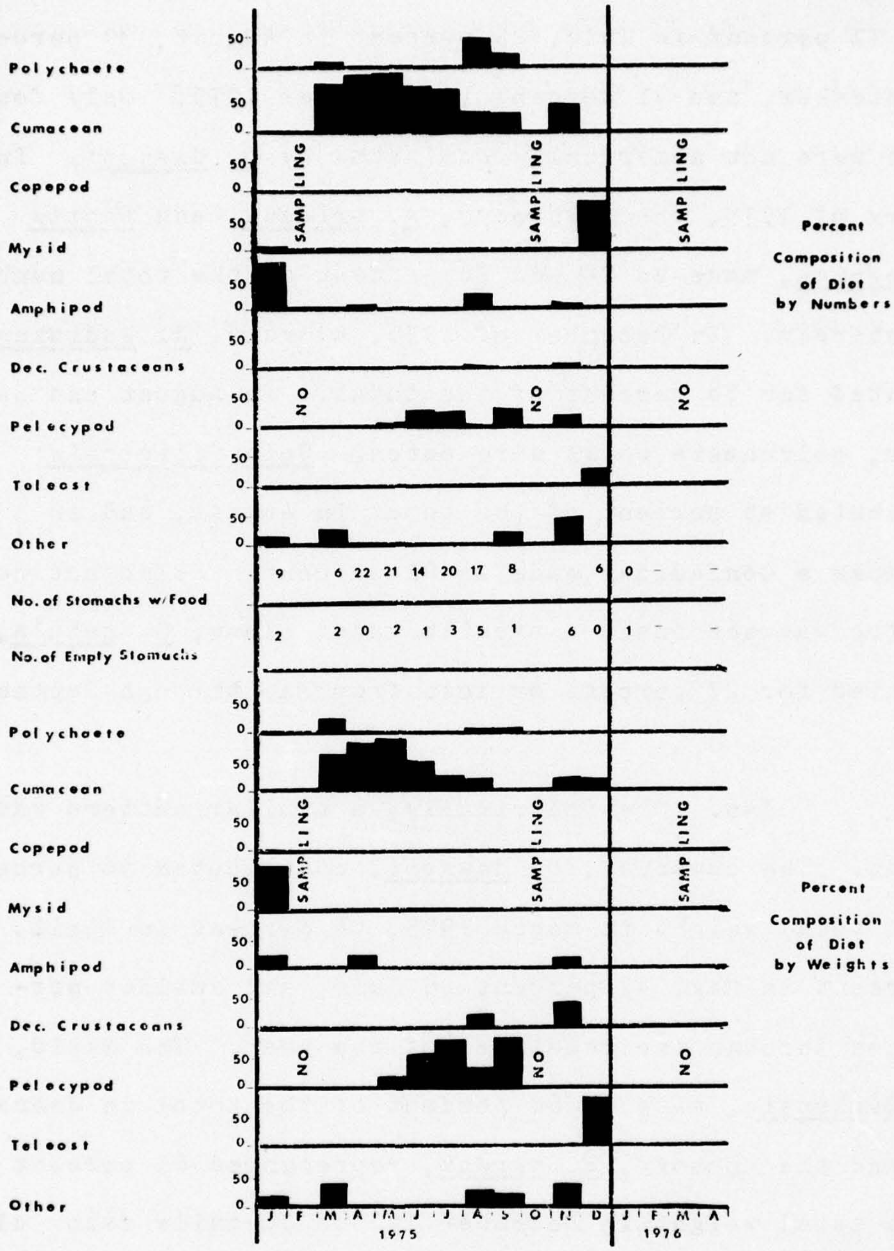

Figure E38. Monthly comparisons of English sole expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

June, 71 percent in July, 25 percent in August, 30 percent in September, and 41 percent in November 1975. Only four months were not numerically dominated by D. dawsoni. In January of 1975, the amphipods, A. tridens and Photis californica, made up 74 and 26 percent of the total number, respectively. In December of 1975, a mysid, N. kadiakensis, accounted for 78 percent of the total. In August and September, polychaete worms were eaten. Spio filicornis contributed 45 percent of the total in August, and in September a Goniadidae made up 21 percent. Pelecypod consumption was seasonal. Juvenile razor clams, S. patula, accounted for 27 percent or less from May tnrough September 1975.

146. Gravimetrically, a similar pattern was evident. The cumacean, D. dawsoni, contributed 56 percent of the total weight in March 1975, 84 percent in April, 82 percent in May, 47 percent in June, and smaller percentages through the remainder of the year. The mysid, N. kadiakensis, made up 60 percent of the total in January 1975 and the anchovy, E. mordax, represented 65 percent of the total weight in December 1975. Juvenile razor clams, S. patula, were more important in terms of weight than in numbers. They contributed 11 percent of the total weight in May 1975, 48 percent in June, 76 percent in July, 16 percent in August, and 77 percent in September 1975. In November, juvenile shrimp, Crangon sp., accounted for 32

percent of the total weight.

147. In summary, the cumacean, *D. dawsoni*, was by far the most important food item to the English sole. *D. dawsoni* was consumed in quantity throughout the year. Juvenile razor clams, *S. patula*, were consistently important prey items from May through November. The basic diet was supplemented some months with polychaete worms, mysids, amphipods, juvenile shrimp, or anchovies. Additional food items which were consumed at least once were:

Polychaete:
- Unident. polychaete
- Nereidae
- Worm fragments
- *Eteone* sp.
- *Spiophanes* sp.
- *Nephtys* sp.
- Ampharetidae
- Syllidae
- *Nothria* sp.
- *Arabella* sp.
- *Glycinde picta*

Cumacean:
- *Colurostylis occidentalis*
- *Hemilamprops* sp.
- *Mesolamprops* sp.

Mysid:
- *Archaeomysis grebnitzkii*

Amphipod:
- *Monoculodes* sp.
- *Eohaustorius* sp.
- *Ampelisca macrocephala*
- *Synchelidium* sp.
- *Photis* sp.
- *Paraphoxus* sp.

Decapod Crustaceans:
- *Cancer magister* megalops
- *Cancer magister* juv.

Teleost:
- Unident. teleost

Other:
- *Tecticeps* sp. (isopod)
- *Synidotea angulata* (isopod)
- Ophiuroid
- Unident. mineral material
- Unident. organic material

148. English sole were sampled at the experimental site in July and August of 1975. The July sample was taken during disposal. Numerically, the cumacean, *D. dawsoni*, was most important, making up 97 percent of the total in July and 60 percent in August. The August diet was supplemented by mysids, *N. kadiakensis*, juvenile Dungeness crab, and *Crangon* sp. shrimp.

149. By weights, D. dawsoni made up 70 percent of the total weight in July 1975 but dropped to 9 percent in August. In August, the juvenile Dungeness crab made up 37 percent of the total weight. Other items occurring in the August diet were juvenile shrimp, juvenile razor clams, amphipods, and debris. The differences noted during the disposal period in August were a decrease in the number of cumaceans eaten and an increase in the number of decapod crustacean juveniles consumed.

150. Figure E39 shows the comparison of the test site to the other four sites from July 1975 through April 1976. In July, fish caught at the test site had not consumed pelecypods, whereas they had been eaten at three of the other four sites. In August, the consumption pattern was scattered, but fish caught at the test site consumed a greater variety of items than at the other four sites.

Sand sole (*Psettichthys melanostictus*)

151. The sand sole is a right-eye flatfish with brown coloration restricted to the right side. The mouth is large, strongly toothed, and almost symmetrical. The scales are ctenoid on the eyed side and cycloid on the blind side. Sand sole reach a length of 63 cm and are found in relatively shallow waters (<183 m) from southern California to the Bering Sea. Distinguishing characteristics of this fish are the large mouth and that the first eight

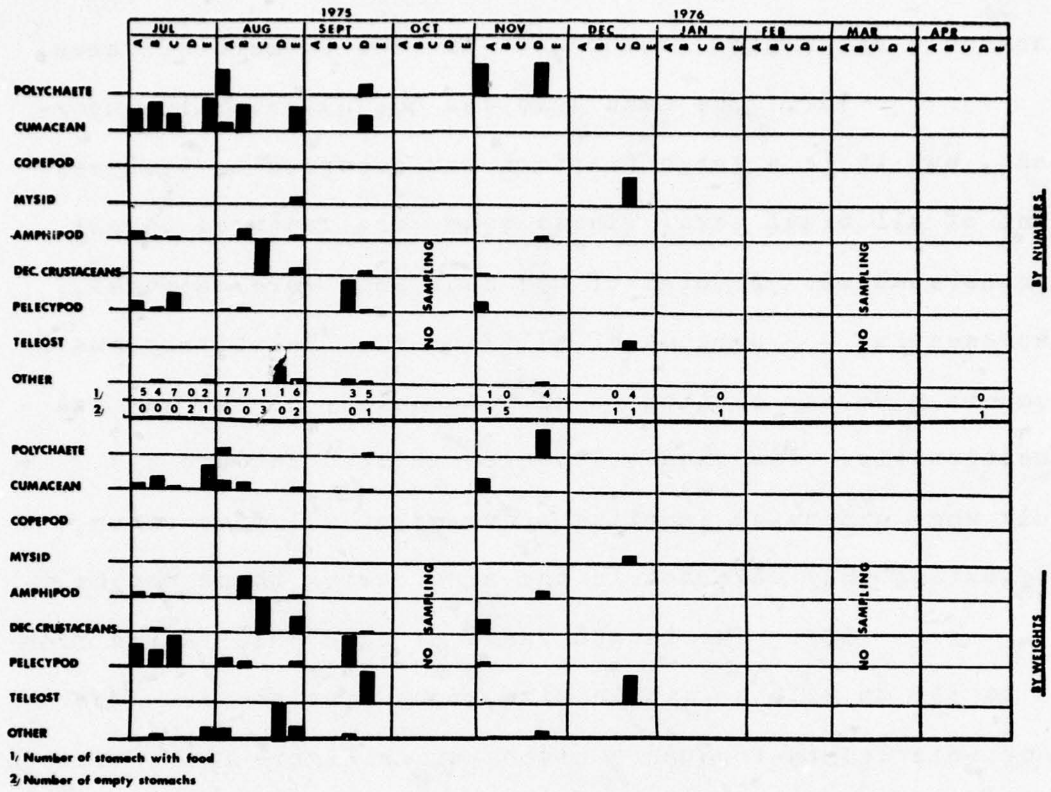

Figure E39. Comparisons of five sampling sites by month for English sole expressed as percent composition of diet by numbers and weights, July 1975 through April 1976.

or more dorsal rays are elongated and filamentous. The sand sole has a good flavor and has some commercial value.

152. The sand sole was not numerically important, but it is a large flatfish and occurred in 55.6 percent of all trawl tows. These sole were captured in all months sampled. A total of 259 sand sole were captured, representing 0.3 percent of all finfish. Relatively small numbers made any estimation of seasonality of the species questionable. Few sand sole were captured in June and July when extensive sampling occurred at all five sites, suggesting they were not in the area during these months.

153. The length range of sand sole varied from 45 to 555 mm with no single size group distinctive. The sand sole length-frequency histogram in Figure E40 indicates a general ungrouped assemblage of all size groups. Examination of sand sole caught at test site E indicated that more small fish were in that area in August and September than in the four remaining sites combined. A test of the comparative sizes between sites had essentially no value because the number captured was small.

154. An ANOVA for sand sole catches was made to determine significance of site and month differences. The tests showed that significant differences existed between numerical catches between sites and between months. However, the differences between sites appeared to be consistent from month to month as indicated by the nonsignificant

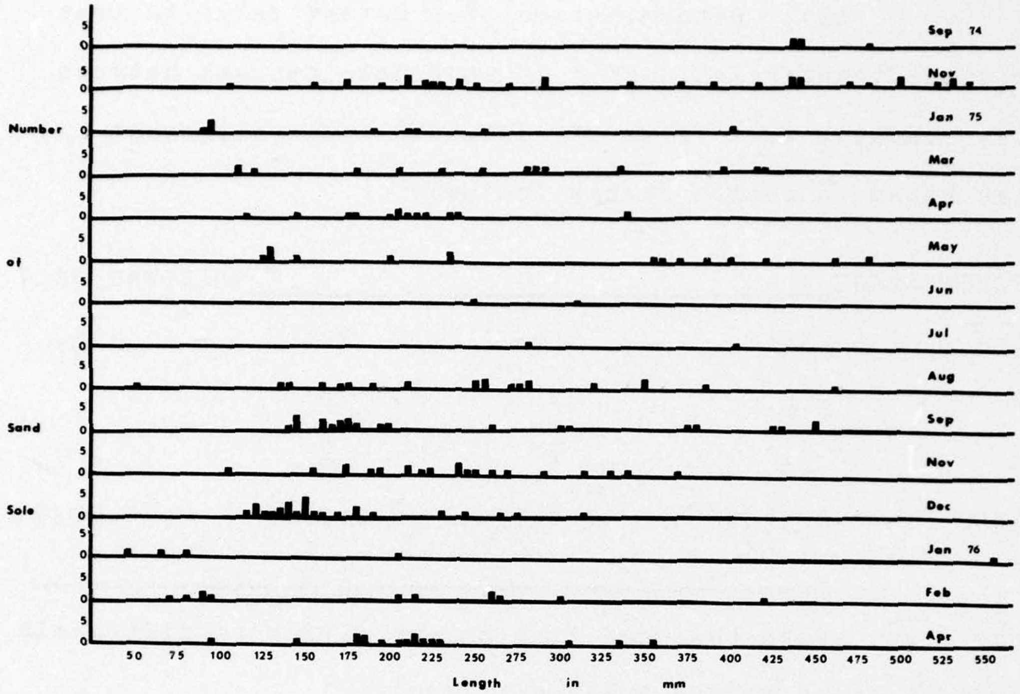

Figure E40. Monthly length-frequency histogram of sand sole (Psettichthys melanostictus) captured with 8-m trawl net.

interaction.

155. Determination of a Q-test value to test the significant relationship of sand sole catches between sites resulted in a value of $z=0.6470$. The alignment of sites based on their catches follows:

LARGEST MEAN ________________________________ SMALLEST MEAN

Site	Site	Site	Site	Site
E	C	A	D	B
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
1.4050	0.7488	0.4475	0.3463	0.2238

Those means above the same line do not differ significantly from each other at the 5 percent level.

156. The Q-test of mean catches for the five sites indicates a significant difference between catches at test site E and the remaining four sites. Trawl catch differences between the other four sites were not significant. The test substantiates the comparatively higher catches of sand sole at test site E.

157. Sand sole are large flatfish with strongly developed teeth, large mouths, and high capacity stomachs, allowing consumption of large or many food items (Figure E41). Numerically, two groups of organisms were important: mysids and fish. The mysid, _N. kadiakensis_, accounted for 78 percent in April, 93 percent in August, and 84 percent in

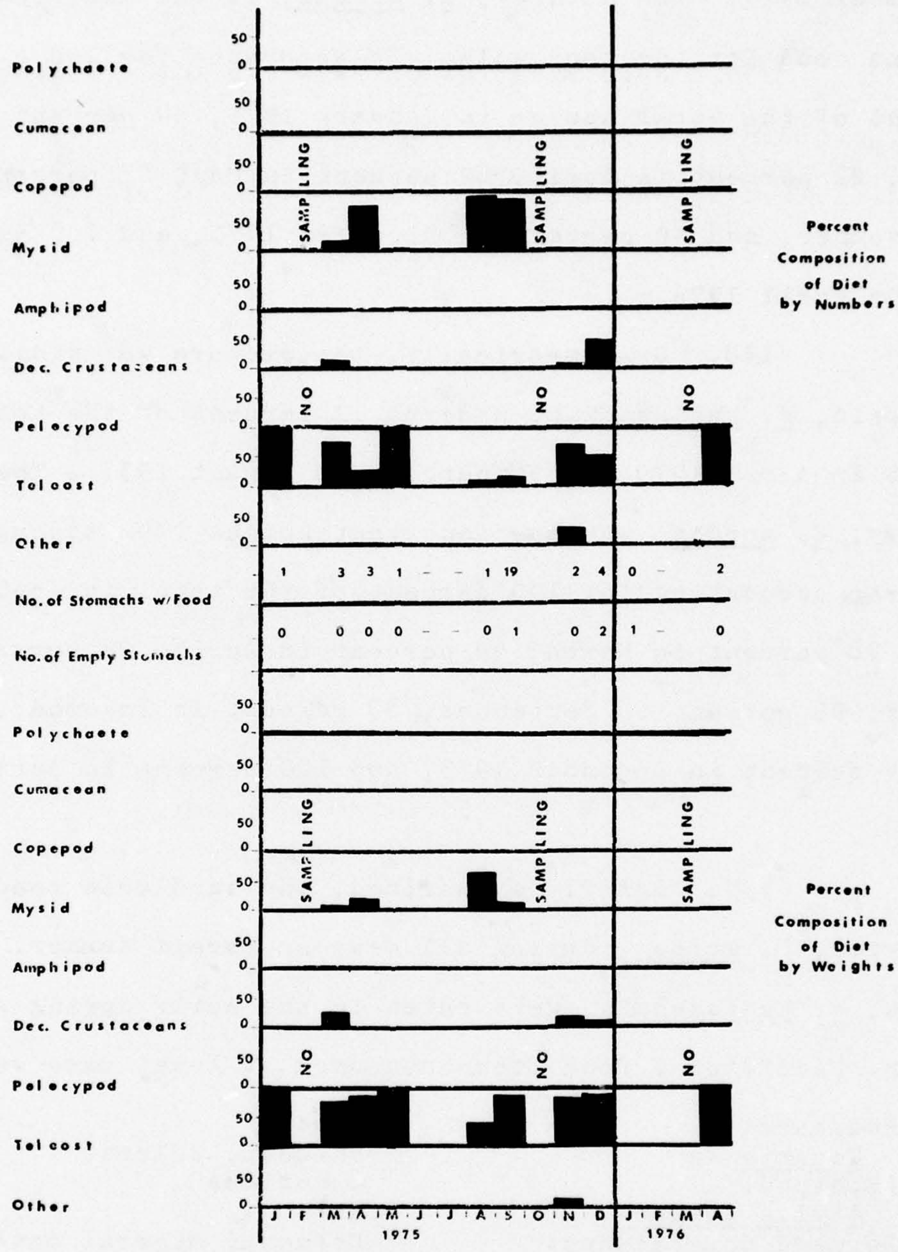

Figure E41. Monthly comparisons of sand sole expressed as percent composition of diet by numbers and weights, January 1975 through April 1976.

September 1975. The anchovy, _E. mordax_, is the most important food for the sand sole. It accounted for 100 percent of the total number in January 1975, 80 percent in March, 22 percent in April, 62 percent in May, 67 percent in November, and 40 percent in December 1975, and 100 percent in April 1976.

158. Gravimetrically, the picture was similar. The mysid, _N. kadiakensis_, made up 11 percent of the total weight in April 1975 and 58 percent in August 1975. The anchovy, _E. mordax_, was the important weight item through the year accounting for 100 percent of the total in January 1975, 78 percent in March, 89 percent in April, 24 percent in May, 95 percent in September, 83 percent in November, and 84 percent in December 1975, and 100 percent in April 1976.

159. Briefly summarized, the sand sole consumed anchovies, _E. mordax_, during all seasons except summer. Mysids, _N. kadiakensis_, were eaten in the early spring and summer. Additional food items consumed at least once were:

Polychaete:
- _Nothria_ sp.

Amphipod:
- _Atylus tridens_

Decapod Crustaceans:
- _Pandalus_ sp.
- _Crangon_ sp.
- _Crangon franciscorum_

Teleost:
- Unident. teleost
- Osmeridae

Other:
- Unident. mineral material
- Unident. animal material

160. Sand sole were sampled at the experimental site, one in August and 19 in September 1975. Numerically,

the mysid, _N. kadiakensis_, was most important, making up 93 and 86 percent of the total, respectively. In August, an unidentified teleost was eaten. In September anchovies were consumed along with the mysids. By weights, the mysids contributed 58 percent and the fish 42 percent of the total for August. In September, the anchovies made up 98 percent of the total weight. It is quite likely that the unidentified teleost is an anchovy digested beyond recognition. The diets for both months were similar.

Decapod Crustaceans

161. Trawling at the sampling sites resulted in the capture of 13 species of decapods representing 5 families. The total number of shellfish captured was 97,360, which exceeded the finfish catch (Table E5). Crangonid shrimp made up 95.9 percent of the entire catch, and _Cancer magister_ accounted for 3.8 percent.

162. Since all but one species of crangonids were grouped, it was not possible to define the decapod crustacean community using diversity, richness, and evenness indices. Use of the catch per minute of trawling effort and index of relative importance (Pinkas et al., 1971) did provide two measures to compare the decapod crustacean catches at each site.

163. The trawl catch of crustaceans at five sites is shown as numbers per minute of effort in Figure E42.

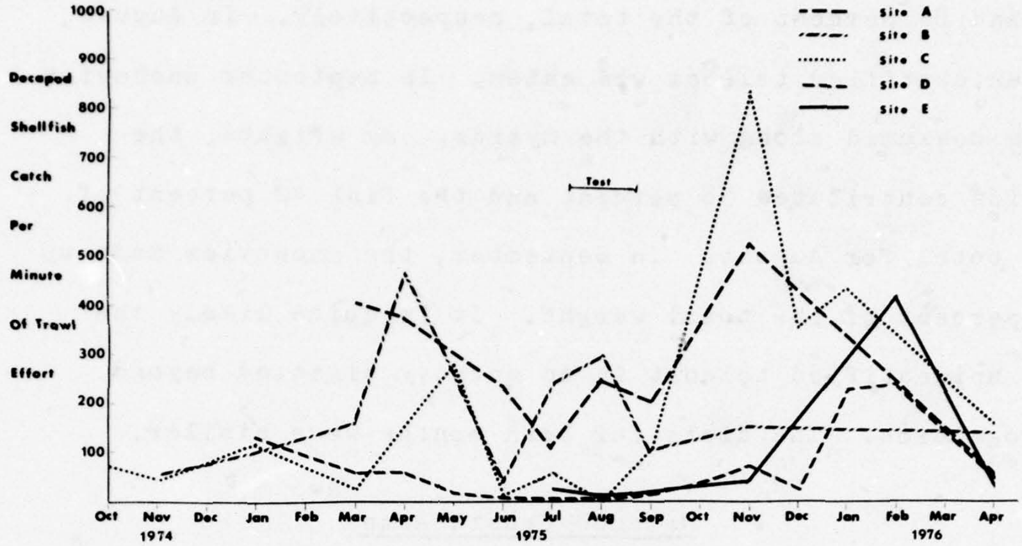

Figure E42. Comparative numerical catch of decapod shellfish per minute of trawl sampling effort between October 1974 and April 1976.

The largest quantities per tow were captured between November 1975 and February 1976, while secondary catches of crustaceans appeared from April to May 1975. Low catches occurred during November 1974 to January 1975 and June to September 1975. A consistent pattern of availability was not apparent at sample sites although further sampling may have produced seasonal trends. The crustacean catch at experimental test site E was less than 30 individuals per minute of trawling effort until deposition of dredged material ceased. The catches increased gradually in November 1975 and then increased to over 420 per minute in February 1976. The April 1976 crustacean numbers at all five sites decreased from the previous month's catches. While crustacean catches at site E were generally lower than catches at other sites, catches at site D also remained low during the deposition period.

164. An index of relative importance (IRI) for the crustacean catches is presented in Figure E43. Importance of sand shrimp in percent number, percent weight, and frequency of occurrence decreased steadily from site A to site E. The remaining grouped crangonid species increased in all categories from site A to site B. Dungeness crab, while never numerically important in terms of percent of the total catch, formed the dominant percent of weight at each of the five sites. The chart reveals the relative insignificance of decapod crustaceans other than crangonid

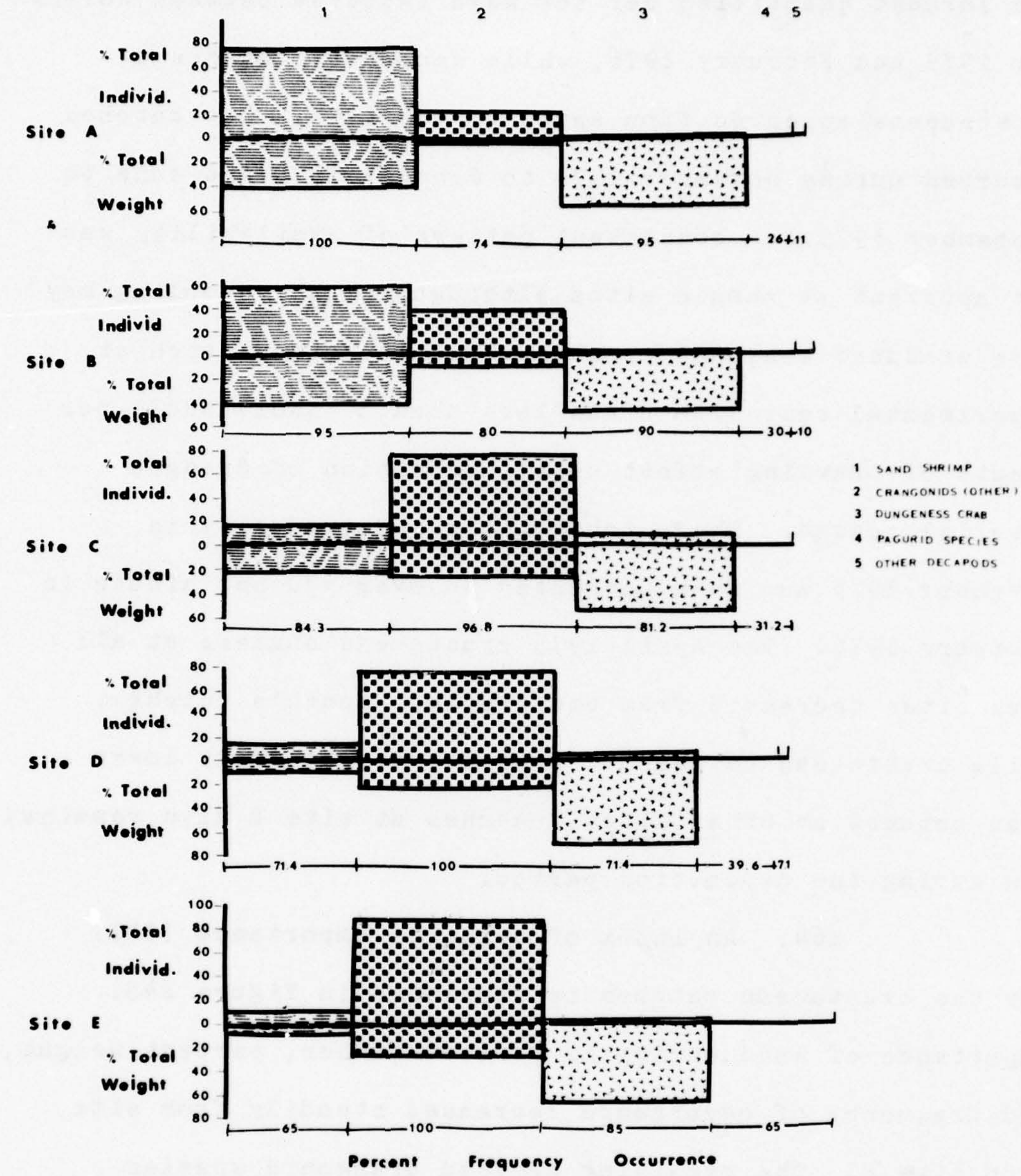

Figure E43. Index of relative importance for several different groups of decapod crustaceans captured from October 1974 to April 1976.

shrimp and Dungeness crab.

165. The sand shrimp and Dungeness crab were the only species used to compute a numerical ANOVA at the five sites. A Q-test and monthly length-frequency were also determined for the two species. It was possible to use a Kolmogorov-Smirnov two-sample test for sand shrimp in April 1976 but not in other months. The egg-bearing period for sand shrimp is shown by percentage of catch with eggs each month. The varying sex ratio of adult male and female Dungeness crab captured at the sites is also presented on a monthly basis.

<u>Sand shrimp</u> (<u>Crangon franciscorum</u>)

166. Sand shrimp are found from San Diego, California to southeastern Alaska to depths of 60 m. The literature indicates sand shrimp reach a length of 82 mm although this would appear to be a median size off the Columbia River mouth. The distinguishing characteristics of sand shrimp are long, narrow hands with longitudinal dactyls and head having long antennae. Sand shrimp inhabit estuarine and near-coastal areas over sandy substrate. Although abundant, they are not harvested commercially but do provide food for finfish and are used occasionally as bait.

167. <u>Crangon franciscorum</u> appeared in 87.4 percent of the 151 trawl tows. A total of 43,579 individuals

were taken and they accounted for 44.8 percent of all decapod crustaceans. Sand shrimp were taken every month, but larger numbers were captured from December through July than from August through November.

168. The lengths of a representative sample of sand shrimp ranged from 30 to 110 mm and are plotted on a length-frequency histogram (Figure E44). The chart reveals that the population consisted almost wholly of adult individuals. Age separation by size was not possible because of overlap. Small sand shrimp entered the catch in July and skewed the histogram through September; thereafter, they were as a group not distinguishable. An adequate numerical sample for a comparative test of sand shrimp lengths was available in April 1976. The Kolmogorov-Smirnov test of shrimp lengths at the disposal site with those of sand shrimp taken at the other sites revealed a significant difference in lengths between the sites (Figure E45). The chart indicates a higher proportion of large shrimp was captured at the four northern sites rather than at experimental test site E. It is not known whether this difference in sand shrimp length was related to sediment disposal at the test site or is a normal condition of size-related spatial distribution off the Columbia River mouth.

169. Egg-bearing sand shrimp were examined to determine if temporal differences existed among sites

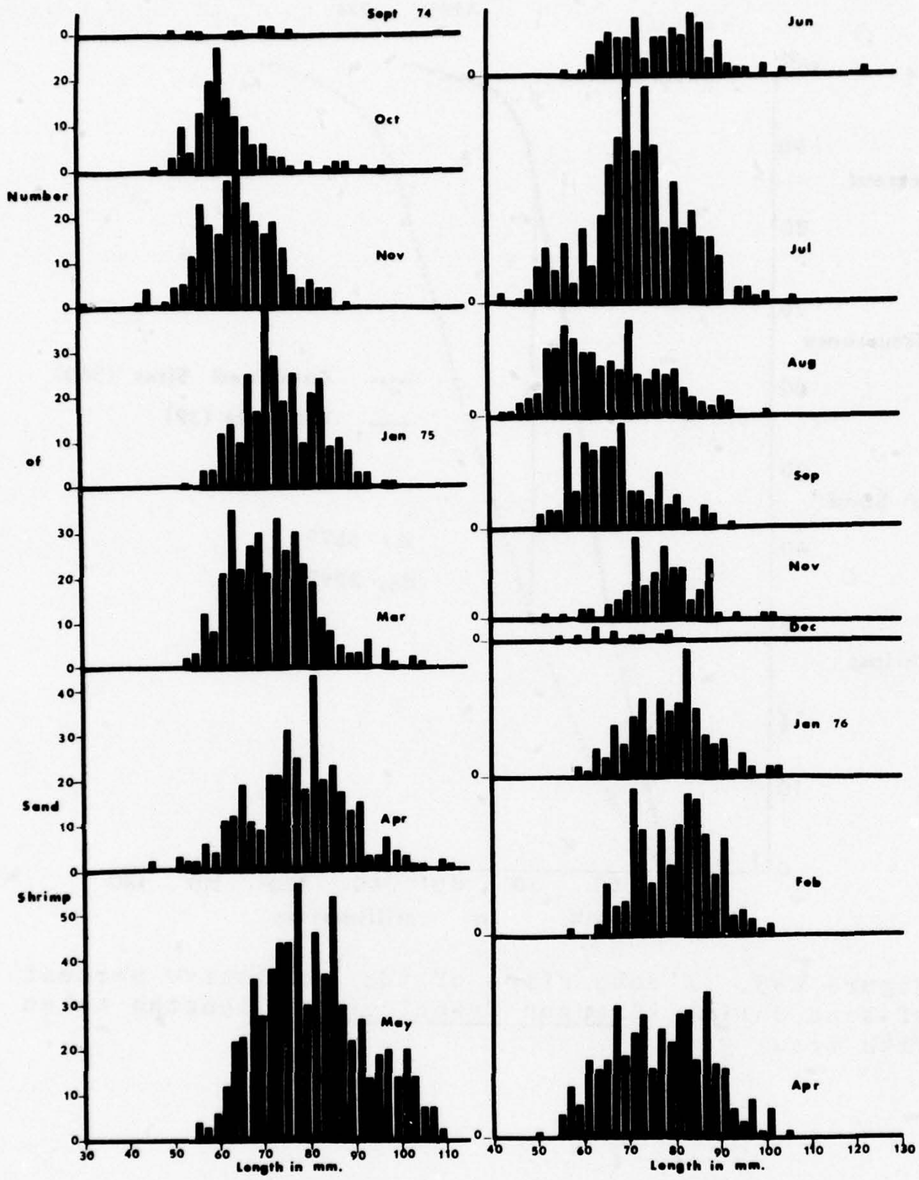

Figure E44. Monthly length-frequency histogram of sand shrimp (Crangon franciscorum) taken at five preselected trawling sites off the Columbia River mouth.

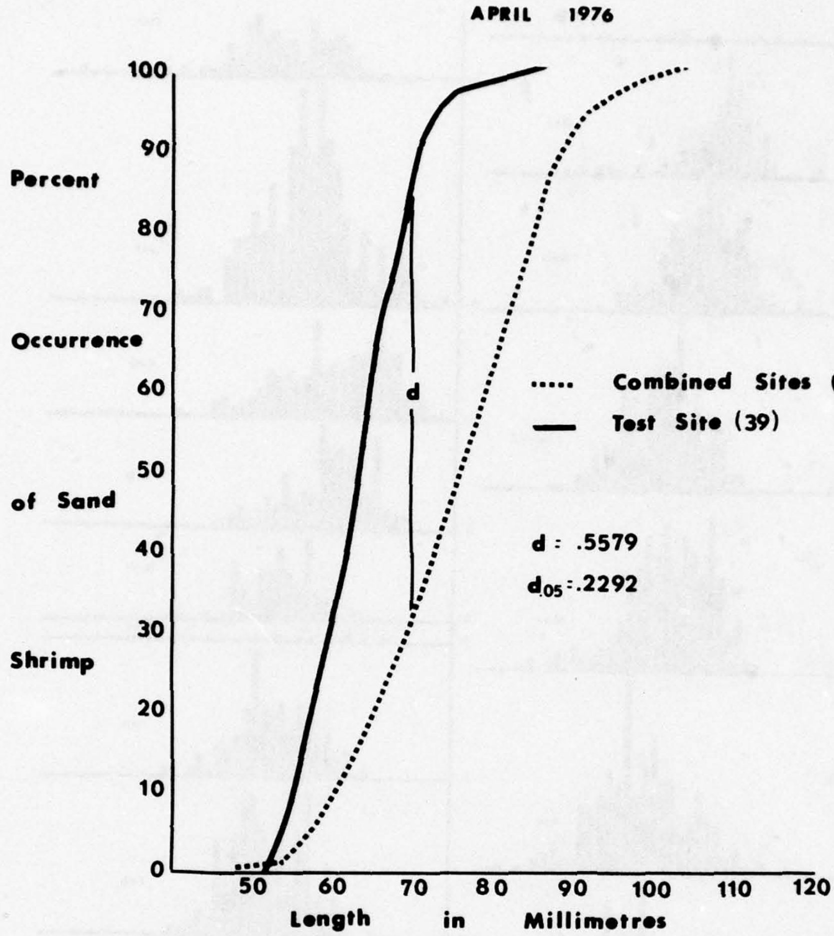

Figure E45. A comparison of the cumulative percent of sand shrimp (Crangon franciscorum) lengths taken with trawl gear.

(Figure E46). The period of time eggs were observed on sand shrimp ranged over six months from January to July. The proportion of egg-bearing peaked between several months at individual sites. The incidence of egg-bearing ranged from 42 to 50 percent between sites. Since sand shrimp were not bearing eggs during sediment deposition and comparatively few were in the test area, it was not possible to measure any impact related to the activity on the species. However, other crangonid species bearing eggs between July and October were common in the area, and any future study of a similar nature should determine if they are affected.

170. An ANOVA of sand shrimp catches and their significance at five sampling sites is shown from July 1975 to April 1976.

	F-value	$F_{.05}$
Site	71.1066	2.87
Month	8.3810	3.10
Interaction	11.0040	2.28

The ANOVA reveals significant differences between months and sites. The differences in catch were not consistent from month to month as indicated by the significant interaction. The sand shrimp catches were similar to catches of some finfish in that larger numbers were taken in northern sites and the monthly catches varied from July to April. Necessary baseline information is unavailable that

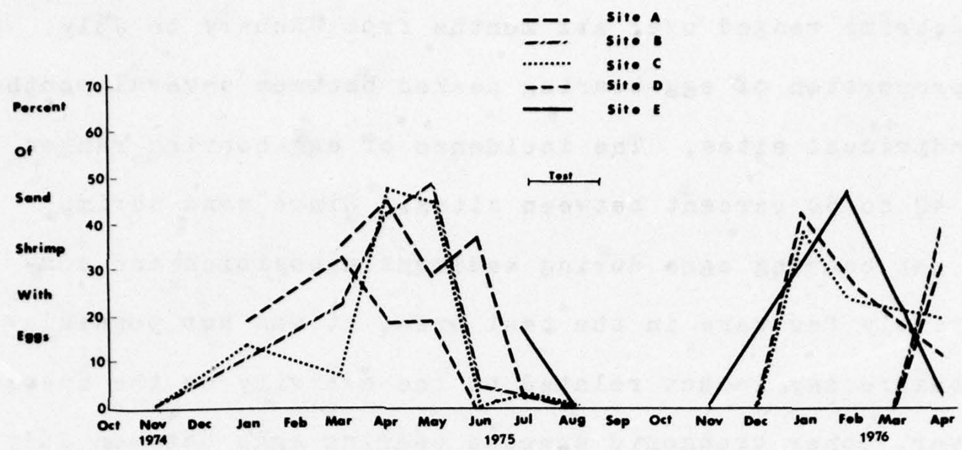

Figure E46. Monthly proportion of trawl-caught sand shrimp bearing eggs.

could have related this distribution pattern to dredging and disposal activities or to normal spatial behavior of the species.

171. A Q-test value $z=1.1568$ was calculated to determine the significance of average abundance per site over time of sand shrimp taken at the study sites. The relationship follows:

LARGEST MEAN ______________________________ SMALLEST MEAN

Site B	Site A	Site C	Site D	Site E
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
6.0312	5.8837	2.0537	1.8125	1.4612

Those means above the same line do not differ significantly from each other at the 5 percent level.

172. Northern sites A and B did not significantly differ from each other; neither did southern sites C, D, and E. The northern and southern sites, however, differed significantly. Test site E had the lowest sand shrimp average abundance of the five sites.

<u>Dungeness crab</u> (<u>Cancer magister</u>)

173. Dungeness crab is one of the important shellfish found on the Pacific coast. It is a hardshell crab measuring up to 25 cm across the carapace. Their range is from Mexico to the Bering Sea. The total commercial

catch varies from 25 to 30 million pounds annually. In addition, recreational harvest is high but most fishing effort is usually confined to protected estuaries or bays. The Dungeness crab occurs to depths of 200 m.

174. Cancer magister were taken in 75.5 percent of the 151 trawl tows. The total number taken was 3662 individuals, and this represented 3.8 percent of all decapod crustaceans. A small but consistent number of adult crab were captured throughout the study, indicating the species is not seasonal. Examination of the sex composition provided a different impression (Figure E47). The ratio of male to female crabs in trawl catches is higher from November through January. From February through October, adult female crabs outnumber male crabs and the ratio is usually disproportionate. Commercial crab harvest begins in December and utilizes male crabs exceeding 159 mm carapace width. A decline in male adults in February would be expected, but the crab season ends in March or April and was not followed by a subsequent recruitment of small adult males for six months. These data suggest that adult crabs are seasonal by sex at the sampling sites.

175. The size of Dungeness crab ranged from 5 to 185 mm width across the carapace. Monthly catches consisted of a numerous small size group and a small group of large crabs (Figure E48). Intermediate-size juveniles or young adult crabs (50-110 mm) were not evident during

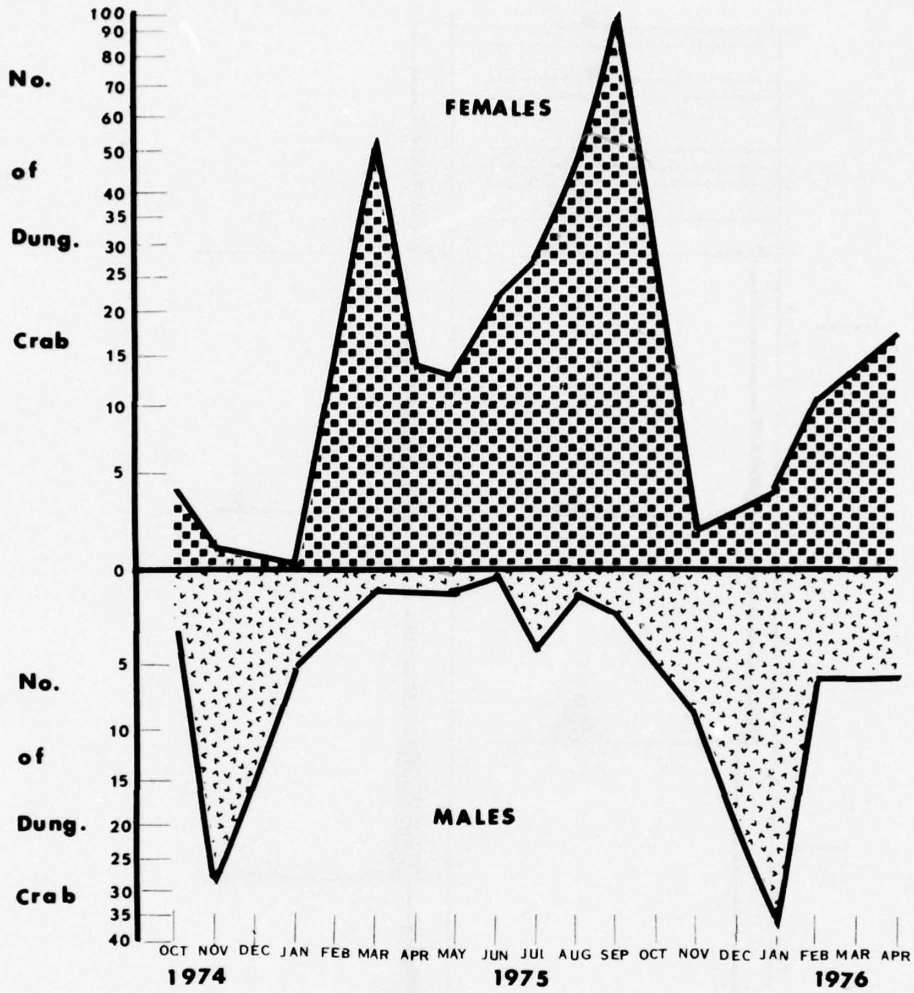

Figure E47. Monthly proportion of mature male and female Dungeness crab captured using a trawl net.

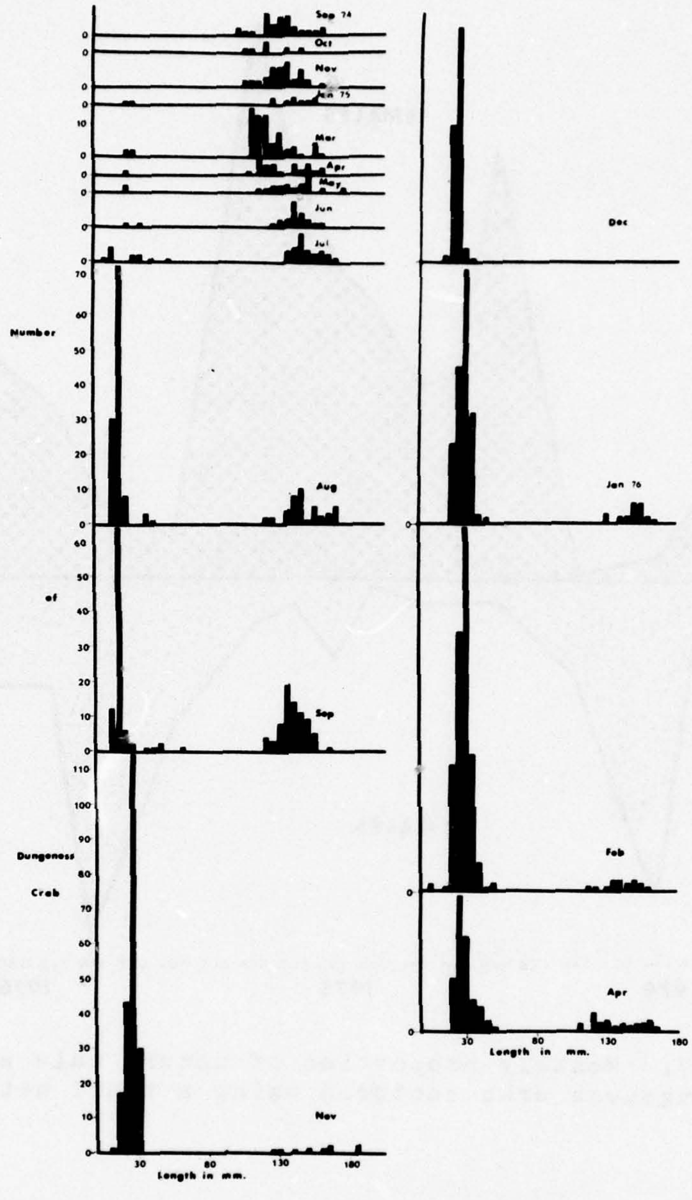

Figure E48. Monthly length-frequency histograms of Dungeness crab (Cancer magister) captured with trawl gear between October 1974 and April 1976.

the study. Insufficient quantities of crab were captured at test site E to make a valid comparison of carapace width with those captured at other sites.

176. An ANOVA for Dungeness crab catches was run to test the differences between sites and months.

	F-value	$F_{.05}$
Site	4.1699	2.87
Month	9.6537	3.10
Interaction	3.9477	2.78

Significant differences existed among sites and also between months at the 5 percent level of significance. The catches of crabs from month to month were not consistent as shown by the significant interaction. The northern sites had numerous juvenile crabs in the summer. In the winter and spring, young crabs were also found at the southern sites. The temporal differences in catches resulted because few crabs were captured in July.

177. A Q-test value of z=1.6595 was calculated for measuring the significance of the difference among mean abundance of crabs at the five sites. The results of this test were as follows:

LARGEST MEAN ———————————————— SMALLEST MEAN

Site B	Site A	Site C	Site E	Site D
$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
2.7312	2.2362	2.1313	1.0038	0.9313

Those means above the same line do not differ significantly from each other at the 5 percent level.

178. The Q-test indicated significant differences in crab catches between northern site B and southern sites E and D. There was no significant difference between sites A and C and the remaining three sites. The tests imply a spatial distribution of Dungeness crab, though it is not as defined as that for several species of finfish.

PART IV: DISCUSSION

179. Trawl sampling for finfish and shellfish off the Columbia River mouth was accomplished on a monthly basis, when weather was suitable and sites unobstructed by fishing vessels or crab pots. Average bottom temperatures and salinities at the five sites were comparable, while currents, tide conditions, wave height, and wind velocity and direction varied considerably between and occasionally within sites. Our average 5-minute trawl effort produced 575.7 finfish and 644.7 decapod shellfish or a combined average of 1220.4 individuals per tow. Finfish species included 21 taken rarely (< 10 individuals) and 10 species numbering less than 100 individuals. Finfish catches in the MCR area were dominated by the remaining 20 species and decapod shellfish were dominated by Crangonidae and Cancridae families.

180. The number and frequency occurrence of some dominant demersal species made it possible to determine seasonality and spatial differences. Presence or absence of schooling species presented difficulties determining their space and time differences. Differences were considered carefully since sampling sites ranged from 2.7 to 9.1 km and depths varied at most by 22.5 m. A logical presumption is that catches at all MCR sites tend to be uniform in numbers and species composition. Previous

sampling (Durkin, 1975) suggested some difference did occur in finfish species and numbers between sites B and C. This study confirms that a spatial difference occurs with some dominant species. Pricklebreast poacher and showy snailfish were important at northern sites while butter sole and Pacific sanddab were important at the southern sites. Whitebait smelt, English sole, and Pacific tomcod were important at all sites. Anchovy and longfin smelt were important at all sites except test site E.

181. Diversity indices were used to compare relationships at the four sites prior to deposition and with test site E following sediment disposal. Indices are useful for determining stress based on a supposition that an undisturbed community supports a large number of species, none of which occur overwhelmingly. Certain types of stress can reduce diversity by making the environment unsuitable or by giving other species competitive advantage (Weber, 1973). Studies by Mearns (1974) in the Southern California bight and Dahlberg and Odum (1970) in a Georgia estuary indicate the Shannon-Weaver indices of 2.0 usually found in the MCR area when anchovy were absent would be considered above average.

182. Charts showing Shannon-Weaver index, species richness, CPUE, and species per tow results provide evidence that the test site finfish population diminished below that of the other four sites and remained low for several months.

The test indices were similar initially to those of other sites, fell during or after deposition, but eventually returned to values corresponding to those from the other sites. These various test indices showed an effect from sediment deposition. Evenness indices at the test site, however, were not depressed but instead moved higher than those at the other four sites. They were highest in September after dredge deposition ceased and remained above the other sites through November. Data revealed several Bothid and Pleuronectid species were taken at the test area and they were present in similar quantities. Environmental stress would normally reduce the evenness index but during this study it increased.

183. Characteristics of eleven finfish species and two decapod shellfish species were studied to determine if any detrimental or favorable effects resulted from the sediment disposal program. These were studied through the 19-month period and particularly the 4-month period during and after sediment deposition when sampling was possible at all sites. Length-frequency histograms portrayed size ranges, growth, availability, and occasionally age groups. Northern anchovy, an important species, were chiefly juveniles, and usually found in schools at northern sites. Wide size ranges over most life stages typified catches of longfin smelt, whitebait smelt, pricklebreast poacher, showy snailfish, English sole, and sand sole. Widely

separated size groups were noted for the Pacific sanddab and Dungeness crab. Pacific tomcod size groups were separate and remained intact. Pacific staghorn sculpin and sand shrimp individuals were usually adults.

184. Relatively small numbers of finfish were taken at test site E during and after deposition. This caused difficulty in comparing species sizes between sites. In nine instances where length comparison could be made with site E, fish were predominantly from nearby sites C and D. These tests indicated 8 situations where a difference existed either at the 5 or 10 percent probability level between the length composition of fish at the test site and other sites. The charts also showed fish at the test site were usually smaller than those found at the other sites. Butter sole were the only species common enough to provide data through the 4-month comparison period. They were initially larger at the test site in July 1975, significantly smaller in August and September 1975, and significantly larger in April 1976. Pacific sanddab (August sample), English sole, whitebait smelt, sand shrimp, and longfin smelt were smaller at the test site than at the combined other sites. This suggests an impact on large fish in a sediment deposition area. It also suggests recruitment of smaller individuals of that species to a deposition site. This apparent relationship could also be food associated. This particular characteristic could be examined in more

detail in other studies and a determination made to see if there is application to other species, areas, and time.

185. The ANOVA two-way tests of each dominant finfish and shellfish species consistently showed significant differences between sites and also between months. Usually most differences in catches were not consistent from month to month or between sites as indicated by the significant interaction. The tests demonstrate the dynamic nature of species found at the Columbia River mouth. The Q-tests were based on ANOVA values and established the relationship of individual sampling sites to each other. It also provided a logarithmic numerical comparison of a dominant species taken at each site. Usually the farthest sites were significantly different while the nearest sites were comparable.

186. The data indicate finfish in the area show selective feeding habits. Young fish consume the same prey items as the adults of the same species but selected for the smaller individuals. Therefore, the diets between young and adult fish of a species differed little in terms of species consumed but rather in terms of sizes of the organisms. This was observed during the process of examining stomachs although the data herein are not separated by ages of fish.

187. Four invertebrate and one fish species were consumed extensively by MCR fish: the cumacean, D. dawsoni;

the mysid, N. kadiakensis; the amphipod, A. tridens; the shrimp, Crangon sp.; and the anchovy, E. mordax. Of the many species inhabiting the MCR area that are of prey-item sizes and could be used for food, these five species were consumed consistently by most dominant species throughout the study and at all sites.

188. Feeding changes observed in finfish at the test site following disposal indicate small-size items were not eaten but large shrimp and anchovies were. This could indicate effects of disturbance to the area created by dumping dredged material. However, by November the food habits of fish caught at the test site were similar to those of fish from the other four sites. The contractual time limits of the study prevented annual comparisons of food habit data. It was therefore not possible to verify if the observed trends are normal for the MCR area or specific to 1975 and early 1976.

189. Dominant decapod shellfish species include sand shrimp, C. franciscorum, and Dungeness crab, C. magister. The C. franciscorum have been described as a bay or estuarine species but data reveal they are abundant in a marine environment, particularly in the adult and egg-bearing stages. Krygier and Horton (1975) noted female C. franciscorum found in Yaquina Bay, Oregon are rarely 62 mm total length and males are less (50-52 mm). The study indicates the average length of C. franciscorum off the Columbia River mouth is

70 to 80 mm with some individuals exceeding 110 mm. The spawning or egg-bearing period noted within Yaquina Bay was December through March while our data reveal the egg-bearing period extends until July. These results suggest young *C. franciscorum* use the estuary while older and larger individuals inhabit a marine environment. The majority of *C. franciscorum* were found at northern sites and this persisted through the entire sampling period. One size comparison test in April 1976 indicated small shrimp were at site E. Other crangonid species were predominantly at the southern sites.

190. Dungeness crab populations were marked by seasonal changes of adult male or female crabs and presence of a strong juvenile size group which entered and remained in the area. Intermediate size crabs with 60 to 120 mm carapace width were not captured. Most crabs were caught at northern sites but only at site B were catches significantly different from the southern sites.

191. The 548,519 m^3 of dredged sediment released at site E had an apparent effect upon the number of species, number of individuals, size of the fish, and food they consumed. The finfish population recovered within seven months. Sediment removal from the navigation channel annually exceeds 4,000,000 m^3, but deposition at sites B and C in prior years revealed no apparent lasting effect on the diversity and number of finfish. Our catch data did indicate a larger

concentration of individuals at northern sites; therefore, deposition effects would be greatest in that area. Catches at the unimpacted southern site D indicated finfish numbers are normally low in the summer and this suggests there would be less direct impact from deposition at that site.

PART V: SUMMARY AND CONCLUSIONS

192. Demersal sampling of finfish and decapod shellfish benthic populations from October 1974 to April 1976 resulted in the capture of 184,291 organisms. The total finfish catch was made up of 21 families and 51 species and consisted of 86,931 individuals. In addition, three families had fish larvae which could not be keyed to species. The decapod shellfish group consisted of 97,360 individuals belonging to 5 families and 11 identifiable species. Sampling was conducted at monthly intervals whenever possible at the five sites off the Columbia River mouth. A selected subsample of numerically dominant finfish captured in the trawl tows was injected and segregated for food consumption analysis. Individual lengths and weights were also taken from a random subsample.

193. The initial sampling period, October 1974 through June 1975, though not a full year, was scheduled to provide baseline information on the temporal and spatial distribution of indigenous species at four preselected sites. The second phase of the study (July 1975-August 1975) continued data collection at the four sites but was oriented primarily toward monitoring deposition of dredged sediments at a fifth specific test site. The tests' purpose was to determine changes that occurred within the finfish and decapod shellfish communities. The final phase (September 1975-April 1976) was a continuation of sampling at the five

sites and determination of further change following completion of the sediment disposal test.

194. The effectiveness of the study was limited by the following:

- a. The lack of a complete initial year of baseline sampling prior to sediment disposal to establish temporal and spatial distribution characteristics for the dominant species.
- b. Designation of the test site's location was made shortly before sediment deposition began, limiting predisposal sampling to the extent that a useful comparison of species could not be made with the four preliminary phase sites.
- c. Actual deposition by the hopper dredge at the test site was made in a semicircular track at various distances from the marker buoy, resulting in trawl samples being taken at least part of the time over areas of no deposition.

195. Despite the qualifications indicated for the sampling effort, a series of comparative tests (which included species richness, diversity, evenness, species per tow, and catch per minute of sampling) revealed a 3- to 6-month depressed population of finfish at the experimental test sites. These non-parametric tests further showed that seven months after deposition had ceased, the test site indices were similar to those of the four comparative sites.

196. The ANOVA of numbers of finfish and shellfish taken at the five sampling sites was limited to the months of July, August, and September 1975 and April 1976. Sampling data gathered between September and April could not

be used for comparative analysis because commercial crab gear restricted sampling at several of the sites. Tests of spatial or site differences in catches indicated a significant difference at the 5 percent level in 10 of the 11 finfish species. English sole were the exception with no difference found in catch between sites. The test of temporal or monthly similarity of catches revealed significant differences in the catch of 9 of the 11 species; anchovy and showy snailfish were exceptions. In addition to the overall significant differences between sites, the analysis also indicated that those differences were not consistent from month to month for each species except anchovy, snailfish, and sand sole.

197. A Q-test was used to compare differences in catches between pairs of sites for the 11 species. In all of the Q-tests, English sole were the only finfish that did not have significant differences in catches between at least two sites. Differences in catch were usually between the northern sites A and B and southern sites C, D, and E. The northern assemblage of fish consisted of anchovy, whitebait smelt, longfin smelt, Pacific tomcod, pricklebreast poacher, showy snailfish, sand shrimp, and Dungeness crab. The southern assemblage consisted of shiner perch, Pacific staghorn sculpin, Pacific sanddab, butter sole, and sand sole. The principal species inhabiting the test disposal site were the sand sole, staghorn sculpin, and butter sole.

The consistency of these species and their numbers suggest they might be considered tolerant of sediment disposal.

198. This study demonstrated that certain demersal finfish from the mouth of the Columbia River (MCR) showed fairly selective feeding habits. This interpretation of the data takes into consideration several sampling limitations:

a. Because of natural occurrence or nonoccurrence and sampling inconsistencies, the eleven species of fish were not sampled evenly during all months.

b. Fish may not have consumed the food items from the area in which they were captured.

c. Diel and diurnal migrations of both fish and invertebrates as well as unknown daily foraging habits of fish may have affected the results.

d. Various stages of digestion of the food items limited some of the identifications.

199. Food utilization studies were conducted from January 1975 through April 1976. The sampling procedure was to select a subsample of the numerically dominant species from each tow. This technique had merits but was subjective, resulting in oversampling of some species and undersampling others. The data provided valuable original information regarding the food habits of indigenous species of demersal fish at the mouth of the Columbia River.

200. Four invertebrate and one fish species are the most extensively consumed prey items off the Columbia River mouth. These are the cumacean, *Diastylopsis dawsoni*;

the mysid, Neomysis kadiakensis; the amphipod, Atylus tridens; the shrimp, Crangon sp.; and the anchovy, Engraulis mordax. Food consumption patterns were evident. The anchovy consumed phytoplankton while smelt ate cumaceans, copepods, and small mysids; an exception was the whitebait smelt, which also consumed small anchovies. Pricklebreast poachers consumed mysids while the tomcod and showy snailfish ate cumaceans, amphipods, shrimp, and fish. Pacific staghorn sculpin preyed on shrimp and fish. The large-mouth flatfish, Pacific sanddab and sand sole, accordingly ate large shrimp and/or anchovies while the small-mouth butter and English soles preyed on cumaceans, amphipods, shrimp, clams in summer, and a few fish and worms.

201. Specific changes in finfish feeding behavior were difficult to assess at the test site since an individual fish could have fed in one area and then swam into the test area where it was captured. However, the data indicate that the consumption of small organisms such as cumaceans, copepods, mysids, and amphipods decreased while consumption of shrimp and fish usually increased during and immediately following disposal. In September and November 1975, feeding behavior of the fish at the test site was similar to that of fish caught at the other four sites. Therefore, the burrowing clams and worms utilized during disposal seemed to be replaced by fish and decapod crustaceans as food items. Following disposal, food comsumption

tended to be similar to that at the other sites.

202. The study revealed that it is possible to refine the approach used and, with additional preparation and study, to provide data that would improve the degree and extent of statistical analysis. The data also suggested that summer sediment disposal at sites south of the navigation channel would affect numerically few demersal finfish.

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TABLE E1
DEMERSAL FINFISH SPECIES, NUMBER CAPTURED, AND FREQUENCY OF OCCURRENCE BETWEEN OCTOBER 1974 AND APRIL 1976

FAMILY	GENUS	SPECIES	COMMON NAME	PRIMARY HABITAT	TOTAL INDIV.	PERCENT TOTAL	151 TOWS FREQ. OCCUR.	PERCENT OCCUR.
Myxinidae								
	Eptatretus	stouti	Pacific hagfish	Pelagic	3	.003	3	1.986
Squalidae								
	Squalus	acanthias	Spiny dogfish	Pelagic	39	.044	27	17.880
Rajidae								
	Raja	binoculata	Big skate	Demersal	34	.039	23	15.231
Acipenseridae								
	Acipenser	medirostris	Green sturgeon	Demersal	2	.002	1	.662
Clupeidae								
	Alosa	sapidissima	American shad	Pelagic	1	.001	1	.662
	Clupea	harengus pallasi	Pacific herring	Pelagic	56	.064	12	7.947
Engraulidae								
	Engraulis	mordax	Northern anchovy	Pelagic	40,909	47.059	100	66.225
Salmonidae								
	Oncorhynchus	tshawytscha	Chinook salmon	Pelagic	1	.001	1	.662
Osmeridae								
	Allosmerus	elongatus	Whitebait smelt	Pelagic	6010	6.913	106	70.198
	Hypomesus	pretiosus	Surf smelt	Pelagic	17	.019	6	3.973
	Spirinchus	starksi	Night smelt	Pelagic	864	.993	60	39.735
	Spirinchus	thaleichthys	Longfin smelt	Pelagic	7816	8.991	110	72.847
	Thaleichthys	pacificus	Eulachon	Pelagic	1095	1.259	55	36.423
	Osmeridae	larvae		Pelagic	2931	3.371	81	53.642
Gadidae								
	Merluccius	productus	Pacific hake	Pelagic	22	.025	8	5.298
	Microgadus	proximus	Pacific tomcod	Demersal	3305	3.801	115	76.158
Syngnathidae								
	Syngnathus	griseolineatus	Bay pipefish	Pelagic	43	.049	18	11.920
Embiotocidae								
	Amphistichus	rhodoterus	Redtail surfperch	Pelagic	3	.003	3	1.986
	Cymatogaster	aggregata	Shiner perch	Pelagic	623	.716	66	43.708
	Hyperprosopon	anale	Spotfin surfperch	Pelagic	5	.005	4	2.649
	Hyperprosopon	ellipticum	Silver surfperch	Pelagic	1	.001	1	.662
	Phanerodon	furcatus	White seaperch	Pelagic	16	.018	4	2.649
	Rhacochilus	vacca	Pile perch	Pelagic	1	.001	1	.662
Trichodontidae								
	Trichodon	trichodon	Pacific sandfish	Demersal	1	.001	1	.662
Anarhichadidae								
	Anarrhichthys	ocellatus	Wolf-eel	Demersal	2	.002	2	1.324
Scorpaenidae								
	Sebastes	melanops	Black rockfish	Pelagic	9	.010	8	5.298
	Sebastes	juveniles		Pelagic	90	.103	33	21.854
	Sebastes	paucispinis	Bocaccio	Pelagic	1	.001	1	.662
Anoplopomatidae								
	Anoplopoma	fimbria	Sablefish	Demersal	2	.002	2	1.324
Hexagrammidae								
	Ophiodon	elongatus	Lingcod	Demersal	4	.004	4	2.649
	Hexagrammos	decagrammus	Kelp greenling	Demersal	9	.010	7	4.635

TABLE E1 (concluded)

Cottidae							
Artedius	harringtoni	Scalyhead sculpin	Demersal	1	.001	1	.662
Enophrys	bison	Buffalo sculpin	Demersal	2	.002	1	.662
Hemiliepidotus	spinosus	Brown Irish lord	Demersal	46	.052	12	7.947
Leptocottus	armatus	Pacific staghorn sculpin	Demersal	282	.324	73	48.344
Chitonotus	pugetensis	Roughback sculpin	Demersal	1	.001	1	.662
Agonidae							
Agonus	acipenserinus	Sturgeon poacher	Demersal	28	.032	14	9.271
Occella	verrucosa	Warty poacher	Demersal	223	.256	57	37.748
Odontopyxis	trispinosa	Pygmy poacher	Demersal	1	.001	1	.662
Pallasina	barbata	Tubenose poacher	Demersal	8	.009	5	3.311
Stellerina	xyosterna	Pricklebreast poacher	Demersal	4098	4.714	108	71.523
Cyclopteridae							
Liparis	pulchellus	Showy snailfish	Demersal	2400	2.760	102	67.549
Bothidae							
Citharichthys	sordidus	Pacific sanddab	Demersal	1680	1.932	104	68.874
Citharichthys	stigmaeus	Speckled sanddab	Demersal	259	.297	47	31.125
Pleuronectidae							
Eopsetta	jordani	Petrale sole	Demersal	43	.049	18	11.920
Glyptocephalus	zachirus	Rex sole	Demersal	382	.439	22	14.569
Isopsetta	isolepis	Butter sole	Demersal	7020	8.075	145	96.026
Lyopsetta	exilis	Slender sole	Demersal	3	.003	2	1.324
Microstomus	pacificus	Dover sole	Demersal	789	.907	39	25.827
Parophrys	vetulus	English sole	Demersal	5310	6.108	138	91.390
Platichthys	stellatus	Starry flounder	Demersal	170	.195	42	27.814
Pleuronichthys	decurrens	Curlfin sole	Demersal	1	.001	1	.662
Psettichthys	melanostictus	Sand sole	Demersal	259	.297	84	55.629
Pleuronectidae	larvae		Demersal	10	.011	4	2.649
TOTAL				86,931			

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TABLE E2
ANALYSIS OF VARIANCE FOR ELEVEN SPECIES OF FINFISH CAPTURED AT FIVE SITES WITH AN 8-m SHRIMP TRAWL OFF THE COLUMBIA RIVER MOUTH - JULY, AUGUST, AND SEPTEMBER 1975 AND APRIL 1976.

SPECIES	SITE	MONTH	INTERACTION
p = 0.05 Significance	2.8700	3.1000	2.2800
Anchovy	5.1354	0.6406*	1.4732*
Whitebait smelt	10.0180	4.1611	6.8894
Longfin smelt	19.8413	37.1861	7.7196
Pacific tomcod	45.5343	50.3646	8.9475
Pacific staghorn sculpin	4.0944	12.0480	9.0060
Pricklebreast poacher	13.8247	10.2102	2.6923
Showy snailfish	15.5840	1.1780*	0.9240*
Pacific sanddab	14.7689	50.8147	9.6998
Butter sole	39.7800	22.5960	5.8800
English sole	2.2139*	23.2514	3.4827
Sand sole	9.5812	8.1806	1.5678*

*Underlined values were not significantly different at the 5 percent level.

TABLE E3
SPECIES LIST OF FOOD ITEMS COLLECTED FROM STOMACHS OF 16 SELECTED SPECIES OF FISH CAUGHT OFF THE COLUMBIA RIVER MOUTH, JANUARY 1975 THROUGH APRIL 1976*

FOOD ITEM	TOTAL NUMBER	TOTAL WEIGHT (gm)
POLYCHAETES		
Unidentified polychaetes	47	10.06
Polychaete fragments	29	1.14
Phyllodocidae:		
Eteone sp.	4	1.61
Syllidae:		
Unid. Syllidae	3	0.03
Nereidae:		
Unid. Nereidae	20	1.79
Nereis sp.	1	0.68
Goniadidae:		
Unid. Goniadidae	12	0.31
Glycinde picta	7	0.72
Glyceridae:		
Unid. Glyceridae	2	3.71
Glycera capitata	1	0.02
Nephtydae:		
Nephtys sp.	9	7.73
Onuphidae:		
Nothria sp.	44	14.17
Arabellidae:		
Arabella sp.	1	0.02
Spionidae:		
Spiophanes sp.	9	0.02
Spiophanes bombyx	1	0.06
Spio filicornis	393	0.93
Ampharetidae:		
Unid. Ampharetidae	19	2.87
Terebellidae:		
Unid. Terebellidae	4	0.00
CUMACEANS		
Lampropidae:		
Lamprops sp.	1	0.02
Hemilamprops sp.	58	0.05
Mesolamprops sp.	1811	6.04
Diastylidae:		
Diastylis sp.	1	0.00
Diastylopsis dawsoni	20141	61.15
Colurostylidae:		
Colurostylis occidentalis	31	0.38
COPEPODS		
Unidentified copepods	2	0.00
Calanidae:		
Calanus sp.	491	0.87
Eucalanidae:		
Eucalanus bungii	2	0.01
Pseudocalanidae:		
Pseudocalanus sp.	51	0.01
Pseudocalanus minutus	2035	0.16
Pontellidae:		
Epilabidocera sp.	1	0.00
MYSIDS		
Unidentified mysids	2	0.01
Family Mysidae:		
Subfamily Gastrosaccinae:		
Archaeomysis grebnitzkii	13	0.06
Subfamily Mysinae:		
Tribe Mysini:		
Neomysis rayii	40	3.52
Neomysis kadiakensis	1447	59.49
Acanthomysis macropsis	3	0.23
Acanthomysis davisi	128	0.96
Acanthomysis nephrophthalma	12	0.30
AMPHIPODS		
Unidentified amphipods	2	0.64
Ampeliscidae:		
Ampelisca sp.	4	0.05
Ampelisca macrocephala	27	0.24

*The sixteen fish are: northern anchovy, whitebait smelt, night smelt, longfin smelt, eulachon, Pacific tomcod, shiner perch, Pacific staghorn sculpin, pricklebreast poacher, showy snailfish, Pacific sanddab, Dover sole, rex sole, butter sole, English sole, and sand sole.

FOOD ITEM	TOTAL NUMBER	TOTAL WEIGHT (gm)
AMPHIPODS - Continued		
Aoridae:		
Unid. Aoridae	2	0.01
Atylidae:		
Atylus tridens	3414	78.11
Gammaridae:		
Elasmopus sp.	1	0.01
Haustoriidae:		
Eohaustorius sp.	1	0.01
Ischyroceridae:		
Ischyrocerus sp.	301	0.19
Lysianassidae:		
Hippomedon denticulatus	19	0.60
Oedicerotidae:		
Monoculodes sp.	90	0.21
Synchelidium sp.	15	0.06
Synchelidium shoemakeri	5	0.10
Photidae:		
Photis sp.	13	0.12
Photis californica	115	0.10
Phoxocephalidae:		
Paraphoxus sp.	3	0.11
Paraphoxus obtusidens	7	0.28
Pleustidae:		
Pleusymptes subglaber	3	0.01
Podoceridae:		
Dulichia sp.	2	0.01
DECAPOD CRUSTACEANS		
Decapod zoea	2	0.05
Anomuran	1	0.02
Crangonidae:		
Crangon sp.	180	131.09
Crangon sp. juveniles	155	36.08
Crangon franciscorum	11	20.04
Cancridae:		
Cancer magister megalops	109	8.67
Cancer magister juveniles	52	39.34
Pandalidae:		
Pandalus sp.	1	0.20
Paguridae:		
Pagurus sp.	1	0.48
PELECYPODS		
Unidentified pelecypods	16	0.45
Unidentified pelecypod juveniles	2	0.00
Solenidae:		
Siliqua patula juveniles	782	55.93
Siliqua patula siphons	556	7.97
TELEOSTS		
Unidentified teleost	21	30.66
Teleost parts	1	0.08
Engraulidae:		
Engraulis mordax	264	538.40
Osmeridae:		
Unid. osmerids	3	37.00
Osmerid larvae	7	3.82
Allosmerus elongatus	3	21.21
Cottidae:		
Unid. cottids	2	10.84
Cottid juveniles	2	0.88
Pleuronectidae:		
Microstomus pacificus juveniles	2	4.13
Isopsetta isolepis juveniles	3	2.24
OTHER		
Unidentified vegetable material**	74	8.36
Unidentified mineral material**	22	3.32
Unidentified animal material**	94	15.61
Unidentified isopod	1	0.00
Tecticeps sp. (isopod)	82	5.28
Synidotea angulata (isopod)	84	6.19
Ophiuroid	12	0.95
Coleoptera part	1	0.01
Dendraster sp. (echinoderm)	2	0.06
Liparid eggs **	4	9.23
Gastropod feet and opercula	11	1.03
Olivella sp. (gastropod)	3	0.81
Nassarius sp.	2	1.94

**Indicates in how many stomachs the material was found.

TABLE E4
FOOD ITEM OCCURRENCE AT THE EXPERIMENTAL
TEST SITE, JULY 1975 THROUGH APRIL 1976

	Pre-disposal JULY	Post-disposal JULY	1975 AUGUST	SEPTEMBER	NO…
POLYCHAETE:	Nothria sp.	--	Nothria sp.	--	
		Nephtys sp.	--	--	
			Unid. polychaete	--	
CUMACEAN:	Colurostylis occidentalis	C. occidentalis	C. occidentalis	--	
	Diastylopsis dawsoni	D. dawsoni	D. dawsoni	--	
COPEPOD:	Calanus sp.	--	--	--	
MYSID:	Neomysis kadiakensis	N. kadiakensis	N. kadiakensis	N. kadiakensis	
AMPHIPOD:	Atylus tridens	A. tridens	A. tridens	A. tridens	
		Synchelidium shoemakeri	--	--	
		Hippomedon denticulatus	--	--	
			Photis sp.	--	
DECAPODS:	Pagurus sp.	--	--	--	
	Cancer magister megalops	C. magister megalops	C. magister megalops	--	
	Crangon sp.	Crangon sp.	Crangon sp.	--	
	Decapod zoea		--	--	
			Decapod megalops	--	
				C. magister juv	
PELECYPOD:	Siliqua patula juveniles	S. patula juveniles	S. patula juveniles	--	
TELEOST:	Unid. teleost	--	Unid. teleost	Unid. teleost	
		Engraulis mordax	--	E. mordax	
			Osmerid larvae	--	
			Isopsetta isolepis juv.	--	
OTHER:	Unid. vegetation	Unid. vegetation	--	--	
	Fish vertebra		--	--	
	Tecticeps sp.		Tecticeps sp.	--	
	Synidotea angulata		S. angulata	--	
	Liparid eggs		--	--	
			Unid. mineral	Unid. mineral	
			Olivella sp.	--	
			Gastropod feet	--	
FISH EXAMINED	3-staghorn sculpin 5-showy snailfish 1-Dover sole 1-English sole 4-Pacific tomcod 1-whitebait smelt 8-butter sole	10-Pacific sanddab 3-English sole 10-butter sole	12-Pacific sanddab 8-English sole 1-sand sole 17-butter sole	19-sand sole 5-butter sole	

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1975	SEPTEMBER	NO SAMPLING IN OCTOBER	NOVEMBER	NO SAMPLING IN DEC. AND JAN.	1976 FEBRUARY	NO SAMPLING IN MARCH	APRIL
	--		*Nothria* sp.		--		--
	--		Nephtydae		--		--
ete	--		--		--		--
			Glyceridae		--		--
			Nereidae		--		--
			Phyllodocidae		--		--
is	--		--		--		*C. occidentalis*
	--		--		--		--
							Mesolamprops sp.
	--		--		--		*Calanus* sp.
							Unid. copepod
s	*N. kadiakensis*		--		--		--
							Unid. mysid
	A. tridens		--		--		*A. tridens*
	--		--		--		*Synchelidium* sp.
	--		--		--		*H. denticulatus*
	--		--		--		*Photis* sp.
							Paraphoxus sp.
	--		--		--		--
egalops	--		--		--		--
	--		*Crangon* sp.		*Crangon* sp.		--
	--		--		--		--
ops	--		--		--		--
	C. magister juveniles		--		--		--
							C. franciscorum
eniles	--		--		--		--
	Unid. teleost		--		--		--
he	*E. mordax*		--		*E. mordax*		*E. mordax*
	--				--		--
lepis juv.	--				--		--
							Pleuronectid juv.
	--		--		--		Unid. vegetation
	--		--		--		--
.	--		--		--		*Pecticeps* sp.
	--		--		--		*S. angulata*
	--		--		--		--
l	Unid. mineral		Unid. mineral		--		--
	--		--		--		--
et	--		--		--		--
					Unid. animal		Unid. animal
							Unid. eggs
anddab	19-sand sole		9-Pacific sanddab		9-Pacific tomcod		3-staghorn sculpn
ole	5-butter sole		5-butter sole		5-butter sole		7-Pac. tomcod
							3-longfin smelt
le							2-whitebait smelt
							2-anchovy
							8-butter sole

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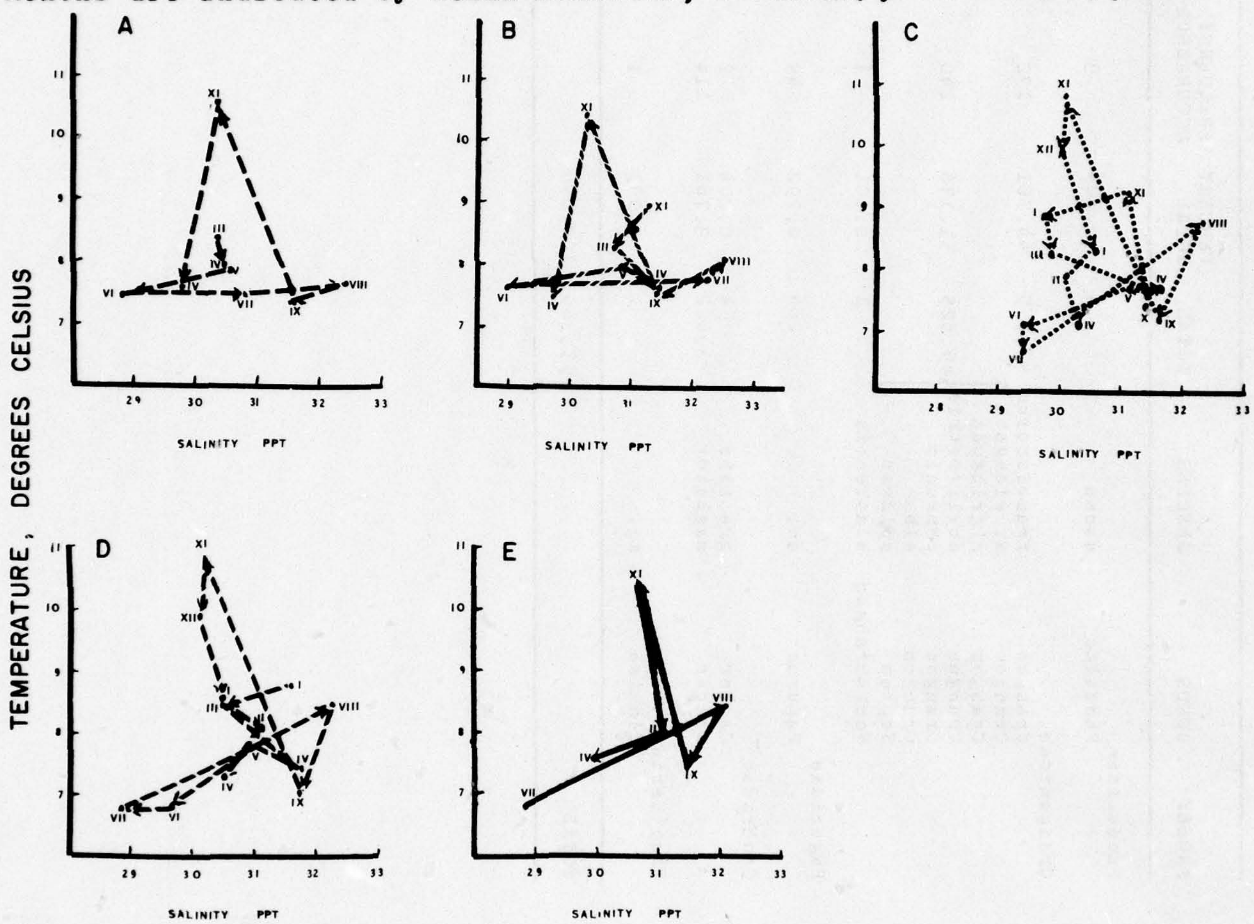
TABLE E5
DECAPOD SHELLFISH FAMILIES AND SPECIES CAPTURED WITH A SHRIMP TRAWL AT FIVE SITES OFF THE COLUMBIA RIVER MOUTH FROM OCTOBER 1974 THROUGH APRIL 1976.

FAMILY	GENUS	SPECIES	TOTAL	PERCENT TOTAL	FREQUENCY OCCURRENCE	PERCENT OCCURRENCE
Pandalidae						
	Pandalus	danae	4	0.004	3	1.99
Crangonidae						
	Crangon	franciscorum	43,579	44.761	132	87.42
	Crangon	a. elongata				
	Crangon	nigricauda				
	Crangon	stylirostris	49,825	51.176	140	92.72
	Crangon	communis				
	Crangon	alba				
	Septem	spinosa				
	Nectocrangon	alaskensis	1	0.001	1	0.66
Paguridae						
	Pagurus	sp.	284	0.292	49	32.45
Cancridae						
	Cancer	gracilis	4	0.004	2	1.32
	Cancer	magister	3,662	3.761	114	75.50
Pinotheridae						
	Pinnixa	sp.	1	0.001	1	0.66
TOTAL			97,360	100.000		

APPENDIX EI

Average monthly salinity and temperature on bottom at each of five sampling sites off the Columbia River mouth October 1974-April 1976. Months are indicated by Roman numerals, I=January, II=February, etc.



APPENDIX EII
FIVE-MINUTE TRAWL TOWS AT SELECTED SITES OFF THE COLUMBIA RIVER MOUTH OCTOBER 1974-APRIL 1976

DATE	NORTH LATITUDE	WEST LONGITUDE	DEPTH RANGE	MAGNETIC COMPASS DIRECTION	DISTANCE OF TOW YARDS	FISH	SHELLFISH
1974							
Oct 1	46°12'55"	124°08'05"	72'-90'	210°		186	11
Oct 1	46°12'50"	124°08'05"	74'-95'	220°		266	44
Oct 1	46°12'45"	124°08'00"	75'-96'	220°		875	206
Oct 1	46°12'40"	124°08'00"	64'-97'	215°		865	513
Nov 15	46°14'45"	124°09'45"	68'-76'	200°	775	406	288
Nov 15	46°14'15"	124°09'45"	71'-75'	200°	775	830	249
Nov 15	46°14'20"	124°09'45"	73'-80'	215°	775	551	78
Nov 15	46°14'20"	124°09'45"	74'-93'	215°	775	572	122
Nov 15	46°12'55"	124°08'05"	85'-82'	100°	700	201	31
Nov 15	46°12'55"	124°08'10"	85'-87'	110°	700	192	39
Nov 15	46°12'55"	124°08'15"	91'-93'	115°	700	587	181
Nov 15	46°12'55"	124°08'20"	97'-96'	120°	700	951	260
1975							
Jan 20	46°12'55"	124°08'10"	72'-76'	210°	1000	575	15
Jan 20	46°12'50"	124°08'10"	74'-118'	200°	800	231	24
Jan 20	46°12'45"	124°08'10"	84'-112'	210°	650	1463	812
Jan 20	46°12'40"	124°08'05"	84'-103'	200°	400	4259	383
Jan 21	46°11'05"	124°08'05"	94'-120'	210°	600	1124	527
Jan 21	46°11'10"	124°08'05"	102'-121'	210°	600	1313	803
Jan 21	46°11'15"	124°08'05"	110'-120'	210°	500	487	229
Jan 21	46°11'20"	124°08'05"	105'-123'	210°	500	254	283
Mar 4	46°12'55"	124°08'05"	90'-102'	200°	800	25	26
Mar 4	46°12'50"	124°08'05"	87'-117'	200°	650	16	13
Mar 4	46°12'45"	124°08'05"	77'-110'	200°	350	177	128
Mar 4	46°12'40"	124°08'05"	80'-102'	250°	250	156	151
Mar 5	46°11'45"	124°08'05"	110'-122'	220°	600	307	265
Mar 5	46°11'05"	124°08'05"	108'-123'	230°	400	319	237
Mar 5	46°11'15"	124°08'05"	110'-120'	225°	400	230	70
Mar 5	46°11'30"	124°08'10"	110'-111'	225°	300	94	54
Mar 11	46°14'40"	124°09'45"	68'-92'	225°	500	210	764
Mar 11	46°14'30"	124°09'45"	66'-84'	225°	400	419	471
Mar 11	46°14'20"	124°09'45"	68'-90'	225°	250	1022	1007
Mar 11	46°14'10"	124°09'50"	72'-77'	225°	250	1323	592
Mar 11	46°15'55"	124°09'45"	60'-87'	225°	300	1359	1418
Mar 11	46°15'45"	124°09'50"	62'-84'	225°	300	613	1664
Mar 11	46°11'05"	124°08'05"	105'-84'	230°	450	125	184
Apr 14	46°15'50"	124°09'45"	61'-92'	215°	800	431	1496
Apr 14	46°15'45"	124°09'50"	71'-93'	210°	800	8144	2286
Apr 14	46°15'35"	124°09'50"	60'-90'	210°	375	138	141
Apr 14	46°15'25"	124°09'50"	58'-85'	210°	400	163	241
Apr 14	46°14'30"	124°09'40"	71'-98'	200°	300	95	480
Apr 14	46°14'25"	124°09'45"	68'-86'	200°	300	177	571
Apr 14	46°14'15"	124°09'40"	64'-75'	200°	250	210	2177
Apr 14	46°14'10"	124°09'40"	70'-81'	200°	200	315	1431
Apr 15	46°12'55"	124°08'05"	83'-107'	190°	400	600	930
Apr 15	46°12'50"	124°08'05"	82'-102'	190°	350	314	620
Apr 15	46°12'45"	124°08'05"	84'-104'	190°	250	211	241
Apr 15	46°12'40"	124°08'05"	88'-102'	190°	200	349	415
Apr 15	46°11'40"	124°08'05"	100'-123'	225°	650	168	119
Apr 15	46°11'45"	124°08'10"	110'-121'	225°	450	929	132
Apr 15	46°11'50"	124°08'05"	98'-118'	225°	250	306	370
Apr 15	46°11'55"	124°08'05"	116'-124'	225°	250	3190	232
May 12	46°10'50"	124°08'10"	104'-118'	225°	600	554	89
May 12	46°11'05"	124°07'55"	118'-124'	230°	350	1569	66
May 12	46°11'20"	124°08'25"	108'-128'	220°	350	896	63
May 12	46°11'25"	124°08'25"	112'-125'	220°	300	163	76
May 13	46°12'50"	124°08'45"	70'-104'	190°	700	665	234
May 13	46°12'45"	124°08'40"	68'-108'	190°	650	1364	781
May 13	46°12'35"	124°08'20"	68'-104'	195°	475	5325	772
May 13	46°14'20"	124°09'50"	91'-104'	195°	350	1599	1983
May 13	46°13'50"	124°09'50"	62'-94'	175°	200	2281	965
May 13	46°14'15"	124°09'35"	67'-80'	175°	300	2669	1709
May 13	46°14'15"	124°09'45"	71'-82'	175°	300	150	448
May 13	46°14'20"	124°09'50"	70'-76'	180°	250	130	488
May 16	46°15'45"	124°09'50"	71'-122'	210°	800	92	281
May 16	46°15'15"	124°09'55"	88'-142'	210°	650	119	772
May 16	46°15'40"	124°09'55"	106'-138'	210°	500	256	2323
May 16	46°15'15"	124°09'50"	82'-104'	210°	350	76	682
June 2	46°14'00"	124°10'15"	72'-141'	210°	450	452	186
June 2	46°14'25"	124°10'20"	73'-138'	210°	700	1071	210
June 2	46°12'45"	124°08'25"	80'-104'	200°	350	846	151
June 2	46°12'35"	124°08'30"	85'-118'	200°	550	764	78

APPENDIX EII (concluded)

June 2	46°12'35"	124°08'30"	85'-118'	200°	550	764	78
June 2	46°11'30"	124°08'05"	110'-122'	220°	450	51	40
June 2	46°11'20"	124°08'10"	108'-116'	220°	375	138	39
June 2	46°15'35"	124°09'50"	58'-112'	210°	400	1180	1585
June 2	46°15'40"	124°09'55"	64'-110'	210°	400	519	746
July 7	46°15'35"	124°09'50"	65'-95'	210°	300	282	279
July 7	46°15'40"	124°10'55"	55'-75'	210°	350	403	339
July 7	46°12'45"	124°08'25"	85'-105'	200°	450	384	341
July 7	46°12'35"	124°08'30"	92'-110'	200°	420	490	165
July 7	46°11'40"	124°06'00"	86'-100'	220°	350	133	123
July 7	46°11'40"	124°06'00"	84'-100'	220°	320	198	176
July 22	46°12'30"	124°08'20"	88'-110'	200°	500	406	9
July 22	46°12'20"	124°08'15"	90'-106'	200°	450	140	24
July 22	46°11'10"	124°08'05"	114'-132'	225°	275	66	28
July 22	46°11'25"	124°08'00"	108'-118'	220°	220	119	39
July 22	46°12'25"	124°07'00"	88'-94'	150°	200	120	87
July 22	46°12'15"	124°07'10"	92'-95'	150°	250	123	58
July 23	46°15'20"	124°10'10"	73'-102'	210°	250	159	756
July 23	46°15'30"	124°09'50"	68'-104'	200°	250	149	1109
July 23	46°14'15"	124°09'50"	72'-84'	210°	200	90	1413
July 23	46°14'10"	124°09'45"	70'-77'	210°	200	79	1017
July 29	46°11'40"	124°06'00"	74'-82'	180°	150	401	148
July 29	46°11'40"	124°06'00"	76'-82'	190°	150	172	254
July 29	46°11'30"	124°06'00"	82'-74'	360°	400	414	342
July 29	46°11'35"	124°06'00"	78'-77'	10°	350	330	195
Aug 22	46°14'25"	124°09'40"	68'-80'	210°	400	737	1603
Aug 22	46°14'20"	124°09'50"	82'-84'	210°	300	576	1353
Aug 22	46°15'20"	124°09'40"	55'-57'	210°	400	622	101
Aug 22	46°15'15"	124°09'50"	56'-83'	210°	450	1410	2271
Aug 21	46°11'40"	124°06'00"	76'-78'	180°	275	189	202
Aug 21	46°11'40"	124°06'00"	72'-81'	180°	300	126	82
Sept 2	46°12'50"	124°08'05"	80'-106'	200°	350	347	4
Sept 2	46°12'45"	124°08'05"	88'-104'	200°	350	181	11
Sept 2	46°11'45"	124°08'00"	110'-121'	215°	300	93	84
Sept 2	46°11'30"	124°08'25"	112'-128'	220°	300	25	11
Sept 2	46°11'40"	124°06'05"	84'-88'	155°	400	158	21
Sept 2	46°11'45"	124°06'00"	81'-85'	165°	400	218	24
Sept 15	46°12'45"	124°08'15"	84'-102'	210°	375	234	1016
Sept 15	46°12'30"	124°08'20"	92'-106'	210°	325	154	26
Sept 15	46°11'35"	124°08'00"	108'-120'	230°	325	61	82
Sept 15	46°11'15"	124°07'50"	107'-121'	230°	230	82	74
Sept 15	46°11'45"	124°06'00"	82'-78'	120°	200	97	118
Sept 15	46°11'40"	124°06'05"	83'-87'	150°	200	55	122
Sept 16	46°14'25"	124°09'40"	78'-84'	210°	300	3198	656
Sept 16	46°14'15"	124°09'45"	75'-104'	230°	300	377	446
Sept 16	46°15'25"	124°09'55"	60'-98'	210°	350	1587	1518
Sept 16	46°15'40"	124°09'50"	62'-84'	210°	300	281	1077
Nov 18	46°12'45"	124°08'15"	86'-96'	200°	325	273	5850
Nov 18	46°12'35"	124°08'20"	75'-97'	195°	375	407	2564
Nov 18	46°11'45"	124°08'25"	102'-122'	210°	350	290	319
Nov 18	46°11'50"	124°08'10"	100'-118'	210°	350	397	405
Nov 25	46°11'40"	124°06'00"	62'-78'	145°	300	65	203
Nov 25	46°11'35"	124°06'05"	74'-82'	160°	250	50	248
Nov 25	46°14'15"	124°09'35"	81'-96'	220°	350	242	146
Nov 25	46°14'30"	124°09'40"	72'-102'	210°	350	770	1364
Nov 25	46°15'30"	124°09'50"	64'-98'	210°	300	279	2633
Dec 5	46°12'40"	124°08'25"	92'-105'	210°	500	259	2697
Dec 5	46°12'35"	124°08'25"	92'-112'	210°	450	133	899
Dec 5	46°11'30"	124°08'15"	108'-122'	240°	350	58	106
Dec 5	46°11'35"	124°08'10"	112'-118'	230°	350	112	184
Dec 5	46°11'30"	124°08'00"	114'-117'	220°	275	54	151
1976							
Jan 21	46°12'40"	124°08'20"	86'-112'	210°	375	1046	1929
Jan 21	46°12'30"	124°08'25"	91'-106'	200°	400	605	2444
Jan 21	46°11'30"	124°08'00"	116'-117'	205°	350	348	1324
Jan 21	46°11'35"	124°07'45"	110'-114'	215°	350	227	990
Feb 21	46°11'50"	124°06'05"	79'-82'	150°	260	361	2219
Feb 21	46°11'45"	124°06'15"	81'-82'	140°	275	274	1986
Feb 21	46°11'10"	124°08'10"	114'-132'	270°	300	314	809
Feb 21	46°11'35"	124°08'20"	122'-119'	315°	200	309	1340
Feb 21	46°12'35"	124°08'20"	92'-111'	200°	350	484	1440
Feb 21	46°12'25"	124°08'15"	90'-110'	200°	375	605	1978
April 1	46°11'50"	124°06'10"	75'-81'	135°	375	289	185
April 1	46°11'50"	124°06'15"	88'-80'	135°	400	203	390
April 1	46°11'55"	124°08'15"	114'-124'	210°	600	116	210
April 1	46°11'35"	124°08'30"	112'-128'	210°	450	138	327
April 1	46°12'40"	124°08'20"	91'-110'	195°	200	225	834
April 1	46°12'30"	124°08'15"	78'-108'	195°	225	151	701
April 2	46°14'25"	124°09'55"	92'-92'	210°	360	232	641
April 2	46°14'20"	124°09'55"	89'-104'	200°	200	224	819
April 2	46°15'05"	124°09'45"	61'-64'	155°	325	466	552
April 2	46°15'15"	124°09'50"	68'-72'	155°	375	90	40

APPENDIX EIII

A comparison of 32 5 m and 8 m trawl catches of finfish by species and total numbers. Tows were 5 minutes in duration and when at the same site were parallel with a similar directional heading. Both semiballoon shrimp nets had the same mesh size.

SITE	DATE	5 m NET SPECIES	5 m NET CATCH	8 m NET SPECIES	8 m NET CATCH
C	10-01-74	11	186	13	875
C	10-01-74	11	266	13	865
B	11-15-74	13	551	18	406
B	11-15-74	11	572	14	830
C	11-15-74	14	201	17	587
C	11-15-74	14	192	17	951
C	1-20-75	8	575	16	1463
C	1-20-75	11	231	18	4259
D	1-21-75	14	487	12	1124
D	1-21-75	14	254	18	1313
C	3-04-75	6	25	11	177
C	3-04-75	6	16	11	156
D	3-05-75	10	230	16	307
D	3-05-75	17	94	23	319
B	3-11-75	13	210	14	1022
B	3-11-75	14	419	10	1323
A	4-14-75	13	138	11	431
A	4-14-75	9	163	12	8144
B	4-14-75	8	95	12	210
B	4-14-75	9	177	11	315
C	4-15-75	11	211	12	660
C	4-15-75	10	349	9	314
D	4-15-75	16	168	15	306
D	4-15-75	16	929	15	3190
D	5-12-75	12	896	14	554
D	5-12-75	13	163	14	1569
C	5-13-75	13	669	13	5325
C	5-13-75	8	1364	11	1599
B	5-13-75	7	150	13	2281
B	5-13-75	13	130	12	2669
A	5-16-75	5	92	11	256
A	5-16-75	9	119	8	76
TOTALS		359	10322	434	43876
AVERAGES PER 5 min. tow		11.2	322.6	13.6	1371.1

APPENDIX EIV

EXPLANATION OF THE TWO-WAY ANALYSIS OF VARIANCE

1. The following was the model used in analyzing the Catch per Unit of Effort (CPUE) data.

   $Yijk = \ln(CPUE + 1)$ for site i, month j, and replicate K.

   $= u + S_i + T_j + (St)_{ij} + {}_s ijk.$

   where u is the general mean

   S_i is the effect of site i

   T_j is the effect of month j

   ${}_s ijk$ is $N(0,o^2)$ i.e., normal random variable with mean 0 and variance o^2

   All factors (except replicates) are fixed effects.

2. We cannot consider months as a random sample of time units, nor sites as a random sample of sites. (The only possible exception, in the case of sites, would be to consider the two control sites as a random sample of sites where no disposal has occurred.)

3. There is no reason for interjecting an artificial stratification when the main purpose is to compare sites. Also there is no prior knowledge to justify stratification of sites into north-south groups. Hence, we cannot consider sites A and B as a random sample of sites in stratum 1.; nor are sites D and E a random sample of sites in stratum 2.

APPENDIX EV: GENERAL DESCRIPTION OF FOOD ORGANISMS

Polychaetes

1. Polychaetes are segmented, soft-bodied aquatic worms of a distinct morphology. They are numerous, diverse, almost entirely marine, and often constitute a major component of benthic communities (Blake, 1975). Some are entirely free swimming while others may be crawlers, burrowers, or tube builders. Among their habitats are sand, mud, under rocks, in algal holdfasts, or on floats.

2. In this geographic region, polychaetes are important since they often account for a significant portion of the species and biomass of the benthos (Lie, 1968; Banse and Hobson, 1974).

3. Polychaetes encountered during this study as food items were:

Unidentified polychaetes
Polychaete fragments
Phyllodocidae:
  Eteone sp.
Syllidae:
  Unidentified Syllidae
Nereidae:
  Unidentified Nereidae
  Nereis sp.
Goniadidae:
  Unid. Goniadidae
  Glycinde picta
Glyceridae:
  Unid. Glyceridae
  Glycera capitata
Nephtydae:
  Nephtys sp.
Onuphidae:
  Nothria sp.
Arabellidae:
  Arabella sp.
Spionidae:
  Spiophanes sp.
  Spiophanes bombyx
  Spio filicornis
Ampharetidae:
  Unid. Ampharetidae
Terebellidae:
  Unid. Terebellidae

4. Polychaete worms were consumed by the following fish during the study.

Longfin smelt	Pacific sanddab
Pacific tomcod	Butter sole
Showy snailfish	Sand sole

5. Hart (1973) reported the consumption of polychaetes by showy snailfish while Clemens and Wilby (1967) reported the same for Pacific sanddab. The standard references report that butter sole and sand sole eat polychaetes (Clemens and Wilby, 1967; Hart, 1973). The consumption of worms is more widely documented for English sole (Frey, 1971; Hart, 1973; and Barss, 1976).

Cumaceans

6. Cumaceans are very small crustaceans, usually one to several millimetres long (Gladfelter, 1975). They usually inhabit the surface layer of sediments from mid-intertidal to great depths. Some species are intertidal. Feeding is by manipulation and cleaning of individual sediment grains, by predation, or by surface deposit feeding (Gladfelter, 1975). They sometimes occur in such vast numbers as to become an important source of food for fishes. The cumacean fauna for the Washington-Oregon area is relatively undescribed (Hart, 1973; Given, 1964; Lie, 1969).

7. Cumaceans encountered during this study as food items were:

Lampropidae:	Diastylidae:
Lamprops sp.	*Diastylis* sp.
Hemilamprops sp.	*Diastylopsis dawsoni*
Mesolamprops sp.	Colurostylidae:
	Colurostylis occidentalis

8. Cumaceans were consumed by the following fish during the study:

Northern anchovy	Pricklebreast poacher
Whitebait smelt	Showy snailfish
Longfin smelt	Pacific sanddab
Pacific tomcod	Butter sole
Shiner perch	English sole

9. Clemens and Wilby (1967) reported the consumption of small crustaceans by anchovies and Hart (1973) reported the same for showy snailfish. Both sources cite small crustaceans as food for longfin smelt. For many local species of fish, the food habits have not been recorded.

Copepods

10. Copepods are small crustaceans that are extremely important in the marine plankton, where they occur in astronomical numbers and occupy a key position in many food chains (Illg, 1975). There exists a great morphological variety of these small animals which may be free swimming, symbionts, or parasites although most are pelagic. About 90 percent of all copepods fall into four orders, the most important being Calanoida. Brodskii (1950) stated this order to be the most important group of marine zooplankton in biomass as well as in number of species. The copepods also are important food objects for many fishes and even some whales (Brodskii, 1950).

11. Copepods encountered during this study

as food items were:

Unidentified copepods
Calanidae:
  Calanus sp.
Eucalanidae:
  Eucalanus bungii

Pseudocalanidae:
  Pseudocalanus sp.
  Pseudocalanus minutus
Pontellidae:
  Epilabidocera sp.

12. Copepods were consumed by the following fish during the study:

Northern anchovy
Whitebait smelt
Longfin smelt
Pacific tomcod
Pricklebreast poacher

13. The literature contains several references to the consumption of copepods, or at least planktonic crustaceans, by the northern anchovy (Clemens and Wilby, 1967; Hart, 1973; Flynn and Frolander, 1975). Clemens and Wilby (1967) and Hart (1973) cite evidence of small planktonic crustaceans being eaten by longfin smelt.

Mysids

14. Mysids are small, translucent, shrimplike animals commonly found in marine, brackish, and fresh waters. Occurring in the marine plankton and over littoral sand flats, they may form dense flocks and become an available source of food for fish (Russell-Hunter, 1969). Feeding is by filtering particles from the water or by scavenging along the bottom (Schmitt, 1971). Some of the planktonic forms show a diurnal, vertical migration and may be predacious carnivores at night (Russell-Hunter, 1969).

15. Mysids encountered as food items during

this study were:

Unidentified mysids
Family Mysidae:
  Subfamily Gastrosaccinae:
    Archaeomysis grebnitzkii
  Subfamily Mysinae:
    Tribe Mysini
      Neomysis rayii
      Neomysis kadiakensis
      Acanthomysis macropsis
      Acanthomysis davisi
      Acanthomysis nephrophthalma

16. Mysids were consumed by the following fish during the study:

Whitebait smelt	Pacific sanddab
Longfin smelt	Butter sole
Pacific tomcod	English sole
Pricklebreast poacher	Sand sole
Showy snailfish	

17. Russell-Hunter (1969) stated that mysids are often food for fish such as flounders. Clemens and Wilby (1967) documented small crustaceans as food for anchovy, longfin smelt, and sand sole, but do not mention mysids specifically. Hart (1973) mentioned crustaceans as food for longfin smelt and mysids for showy snailfish.

Amphipods

18. Amphipods are represented locally by three suborders, one of which contains the amphipods consumed by the fish during this study. The Gammaridae occur in fresh and marine waters and in the semiterrestrial supralittoral fringe of the shore (Smith and Carlton, 1975). Some may undergo nightly vertical migrations (Barnard, 1969).

The gammaridean fauna of the Washington-Oregon coast has been inadequately studied (Kozloff, 1974). The amphipods have specialized appendages for purposes such as swimming, crawling, burrowing, grasping, feeding, etc.

19. The amphipods encountered during this study were:

Unidentified amphipods
Ampeliscidae:
  Ampelisca sp.
  Ampelisca macrocephala
Aoridae:
  Unid. Aoridae
Atylidae:
  Atylus tridens
Gammaridae:
  Elasmopus sp.
Haustoriidae:
  Eohaustorius sp.
Ischyroceridae:
  Ischyrocerus sp.
Lysianassidae:
  Hippomedon denticulatus
Oedicerotidae:
  Monoculodes sp.
  Synchelidium sp.
  Synchelidium shoemakeri
Photidae:
  Photis sp.
  Photis californica
Phoxocephalidae:
  Paraphoxus sp.
  Paraphoxus obtusidens
Pleustidae:
  Pleusymptes subglaber
Podoceridae:
  Dulichia sp.

20. Amphipods were consumed by the following fish during this study:

Longfin smelt
Pacific tomcod
Shiner perch
Pacific staghorn sculpin
Pricklebreast poacher
Showy snailfish
Pacific sanddab
Butter sole
English sole

21. Clemens and Wilby (1967) and Hart (1973) mentioned that longfin smelt consume small crustaceans and that staghorn sculpin eat invertebrates, although amphipods were not specifically named. Clemens and Wilby (1967) documented that shiner perch eat small crustaceans while Hart (1973) recorded that showy snailfish consume amphipods.

Schmitt (1971) recorded that amphipods form the bulk of the food of many animals, particularly fish, including the flounder-like fishes.

Decapod Crustaceans

22. Decapod crustaceans encountered during this study were the crabs and shrimps. The crab occurring most frequently in the samples was the Dungeness, the commercially valuable crab of the Washington-Oregon coast. However, the shrimp found within the stomachs was of a noncommercial variety, *Crangon* sp. Schmitt (1921) recorded that *Crangon* shrimp (formerly *Crago*) taken from San Francisco Bay occurred in muddy areas of the bay.

23. The Dungeness crab is the second most important commercial crab in the United States (Department of Fish and Wildlife, 1974). It is usually found on sandy bottoms and relatively shallow waters but may be found in deeper water. Two of the developmental stages of Dungeness crab were consumed by fish, megalops, and juvenile. Scavenging is probably the most common niche for Dungeness crab, although some have been seen breaking clam and oyster shells (Smith, 1973).

24. Decapod crustaceans encountered during this study as food items were:

Decapod zoea
Anomuran
Crangonidae:
  Crangon sp.
  Crangon sp. juveniles
  Crangon franciscorum
Cancridae:
  Cancer magister magalops
  Cancer magister juveniles
Pandalidae:
  Pandalus sp.
Paguridae:
  Pagurus sp.

25. Decapod crustaceans were consumed by the following fish during the study:

Longfin smelt
Pacific tomcod
Pacific staghorn sculpin
Pricklebreast poacher
Showy snailfish
Pacific sanddab
Butter sole
English sole
Sand sole

26. Several authors have cited the consumption of small crabs and shrimps by English sole (Clemens and Wilby, 1967; Hart, 1973; Barss, 1976). Hart (1973) also cited the consumption of shrimp by butter sole and decapod crustaceans being consumed by showy snailfish. Forsberg et al. (1975), working in Tillamook Bay, Oregon, found that Pacific staghorn sculpin ate small crab and shrimp. However, most literature on the food of the local fishes is inadequate or totally lacking.

Pelecypods

27. Pelecypods are clams. Most of the clams consumed by the local fish were identified as juveniles of the razor clam, Siliqua patula. Shellfish biologists of the Washington State Department of Fisheries (1976) identified another small razor-type clam off the Washington-Oregon coast, Siliqua sloati. The ranges of S. patula

and *S. sloati* apparently overlap. The razor clam is an important resource as a recreational fishery and to a lesser degree as a commercial fishery. This species is an active burrower and lives in the intertidal zone of open beaches (Department of Fish and Wildlife, 1974) out to the littoral zone. They are filter feeders with diatoms forming the large part of its food. While the razor clam may attain a length of 13 to 15 cm, most of the clams found in the fish stomachs were under 2.5 cm in length. In addition, some fish snip off and eat the siphons, leaving the body of the clam.

28. Pelecypods encountered as food items during this study were:

Unidentified pelecypods
Unidentified pelecypod juveniles
Solenidae:
  Siliqua patula juveniles
  Siliqua patula siphons

29. Pelecypods were consumed by the following fish during the study:

Pacific tomcod	Butter sole
Pacific sanddab	English sole

30. The razor clam was consumed mainly by several species of flatfish. English sole have teeth formed into cutting edges adapted for snipping the siphons from lamellibranchs. They also may capture complete clams, with shells, and swallow them whole. The plaice, a related fish, has been reported to feed in a similar manner (Alexander,

1967). Barss (1976) mentioned that English sole feed on clams and clam siphons, as also reported by Clemens and Wilby (1967) and Hart (1973). Both Clemens and Wilby (1967) and Hart (1973) reported that sand sole consume small molluscs as part of their diet, although this species is mainly pisciverous.

Teleosts

31. Since teleosts have been covered elsewhere in this report, little more needs to be written. By far the most important fish used as a food item for other fish was the northern anchovy. During the time when anchovies (juveniles) were demersal (winter), they were consumed frequently and in quantity; in summer when anchovies are more pelagic, they were eaten less.

32. The teleosts encountered as food items during this study were:

Unidentified teleost
Teleost parts
Engraulidae:
  Engraulis mordax
Osmeridae:
  Unid. osmerids
  Osmerid larvae
  Allosmerus elongatus
Cottidae:
  Unid. cottids
  Cottid juveniles
Pleuronectidae:
  Microstomus pacificus juv.
  Isopsetta isolepis juv.

33. Teleosts were consumed by the following fish during the study:

Whitebait smelt
Longfin smelt
Pacific tomcod
Pacific staghorn sculpin
Pacific sanddab
Butter sole
English sole
Sand sole

34. Fish preying on other fish is relatively common in the marine environment. Clemens and Wilby (1967) and Hart (1973) both reported that sand sole feed on anchovies and other small fish. Barss (1976) and Frey (1971) reported that English sole occasionally eat small fish, and Forsberg et al. (1975) commented about examining Pacific staghorn sculpin that had consumed juvenile English sole. Frey (1971) agreed that sculpins do prey on fish. Again, the literature regarding food habits of fish in the area is limited.

Others

35. This category includes the food items not consumed as frequently as the items in the other major food groups. Food items in this category consumed during the study were:

- Unident. vegetable material-including phytoplankton
- Unident. mineral material
- Unident. animal material
- Unident. isopod
- *Tecticeps* sp. (isopod)
- *Synidotea angulata* (isopod)
- Ophiurod
- Coleoptera part
- *Dendraster* sp. (echinoderm)
- Liparid eggs
- Unident. fish eggs
- Gastropod feet and opercula
- *Olivella* sp. (gastropod)
- *Nassarius* sp. (gastropod)

36. It has been reported that anchovies feed on phytoplankton and small zooplankton although on occasion a small fish is consumed (Frey, 1971). Alexander (1967) wrote that the anchovy often feed by swimming forward with mouths and opercula open and the plankton is filtered out by the gill rakers. Baxter (1967) believed anchovies to be

occasionally predatory on other anchovies. Flynn and Frolander (1975) examined five anchovy stomachs from Tillamook Bay and found planktonic and epibenthic organisms including calanoid copepods.

37. It was some of the larger flatfish that consumed the gastropods while several species of fish ate isopods. The liparid eggs were consumed by adult liparid fishes.

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Durkin, Joseph T
Aquatic disposal field investigations, Columbia River disposal site, Oregon; Appendix E: Demersal fish and decapod shellfish studies / by Joseph T. Durkin, Sandy J. Lipovsky, National Marine Fisheries Service, Hammond, Oregon. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1977.
184 p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-77-30, Appendix E)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under DMRP Work Unit No. 1A07E.
Literature cited: p. 149-159.

1. Columbia River. 2. Disposal areas. 3. Dredged material disposal. 4. Fishes. 5. Sediment. 6. Shellfish. I. Lipovsky, Sandy J., joint author. II. United States. Army. Corps of Engineers. III. United States. National Marine Fisheries Service. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; D-77-30, Appendix E.
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